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A PARADISE FOR PLANT LOVERS

THE BIOLOGICAL STATION AT ALTO DA SERRA, BRAZIL

By Dr. ALBERT F. BLAKESLEE

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ONE'S early idea of tropical vegetation is generally obtained from books. It is often with some disappointment, therefore, that in his travels near the equator the tourist fails to find the luxuriant growth of plants of which he has read. The reason the ordinary traveller does not see the optimum vegetation is largely due to the fact that the tourist and business routes in the main avoid localities where the precipitation of water is abundant throughout the year. Where the temperatures are favorable, as is the case in the lower altitudes in the tropics, the most common limiting factor for luxuriant plant growth is the supply of water.

The influence of moisture on the type of vegetation is well shown in islands in the Caribbean where mountains cause precipitation from the moist trade winds and leave the leeward areas on the south relatively dry. Thus, Kingston in the south of Jamaica has a rainfall of around twelve inches and shows a dry-climate vegetation of cacti and other tropical xerophytic plants, while on the north and less populated side of the Blue Mountains a precipitation of as many feet has been reported and the vegetation is accordingly luxuriant. In the Hope Botanic Gardens, in Kingston, Jamaica, an interesting collection of tropical plants is assembled, but the need of more moisture is shown by the presence of a water faucet at the base of each palm tree.

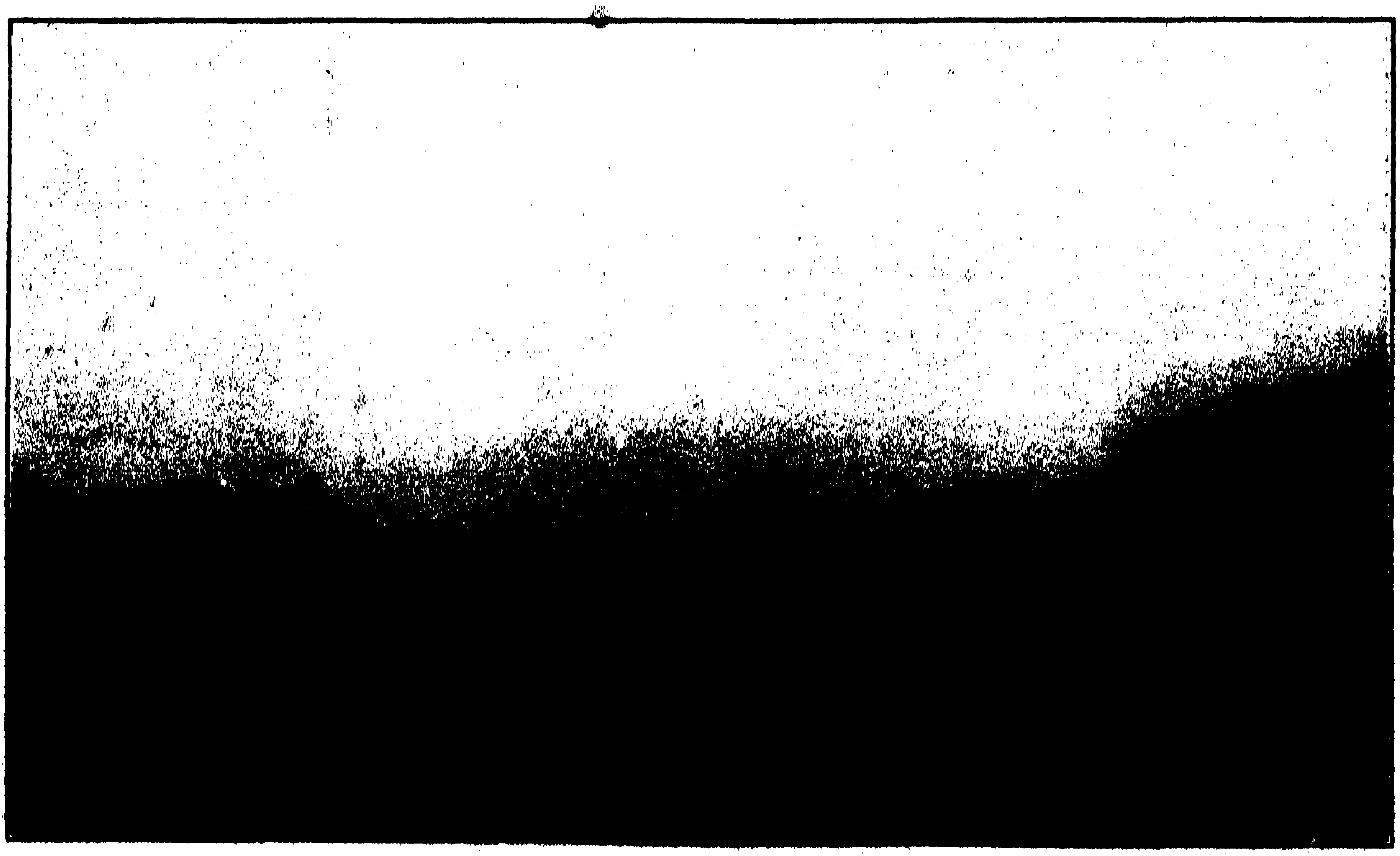
Botanical gardens in South America, as elsewhere, are outdoor museums of plants with an orderly arrangement of living specimens and tend to emphasize the exotic or the rarer elements in the native flora. The Biological Station at Alto da Serra in the neighborhood of São Paulo, Brazil, seems unique in that it not only presents a well-nigh unparalleled luxuriance of virgin plant growth brought about by the humid semi-tropical climate, but, in addition, is located on a main line of travel. In many places it would be almost impossible to penetrate the dense tangle of growth, but a series of foot paths have been cut through, making the interior accessible, but otherwise the place has not been "improved" by the hand of man. It is, in fact, the ideal of Professor F. C. Hoehne, the director of botanical activities in São Paulo, to keep this biological station a virgin sanctuary for native plants and animals—not a cleared park or botanic garden of rare specimens. Trees fall and moulder where they lie. Epiphytes of various species carpet them with green patterns of different shades, leaving at length ridges of varied verdure on the forest floor.

It is a matter of surprise that such a paradise for plant lovers is so little known, even to professional botanists. It had not been mentioned by any one from whom we sought advice regarding our four months' botanical trip around South America as a place that ought to be visited until we were at São Paulo, when Professor Hoehne described the station and suggested our visiting it the next morning. Our plans had been made, however, to leave for Rio on the morning train and we inquired about the possibility of going in the afternoon, but he replied, "You had better stay over another day and go in the morning because it will rain this afternoon. It always does rain at Alto da Serra in the afternoon, but the mornings are clear." Since it was not convenient to change our schedule, he offered to join us in gambling on the afternoon weather and to make the trip after lunch.

Alto da Serra is a railroad station

VIEW LOOKING TOWARD SANTOS

FROM ENTRANCE TO BIOLOGICAL STATION AT ALTO DA SERRA, BRAZIL. EXPOSURE WAS TAKEN IN EARLY AFTERNOON. PHOTO BY A. F. BLAKESLEE.



THE SAME VIEW AS THAT ABOVE

BUT EXPOSURE WAS TAKEN IN THE LATE AFTERNOON. IT SHOWS THE CLOUDS ROLLING UP OVER THE LANDSCAPE—TYPICAL OF AFTERNOONS AT ALTO DA SERRA. PHOTO BY A. F. BLAKESLEE.

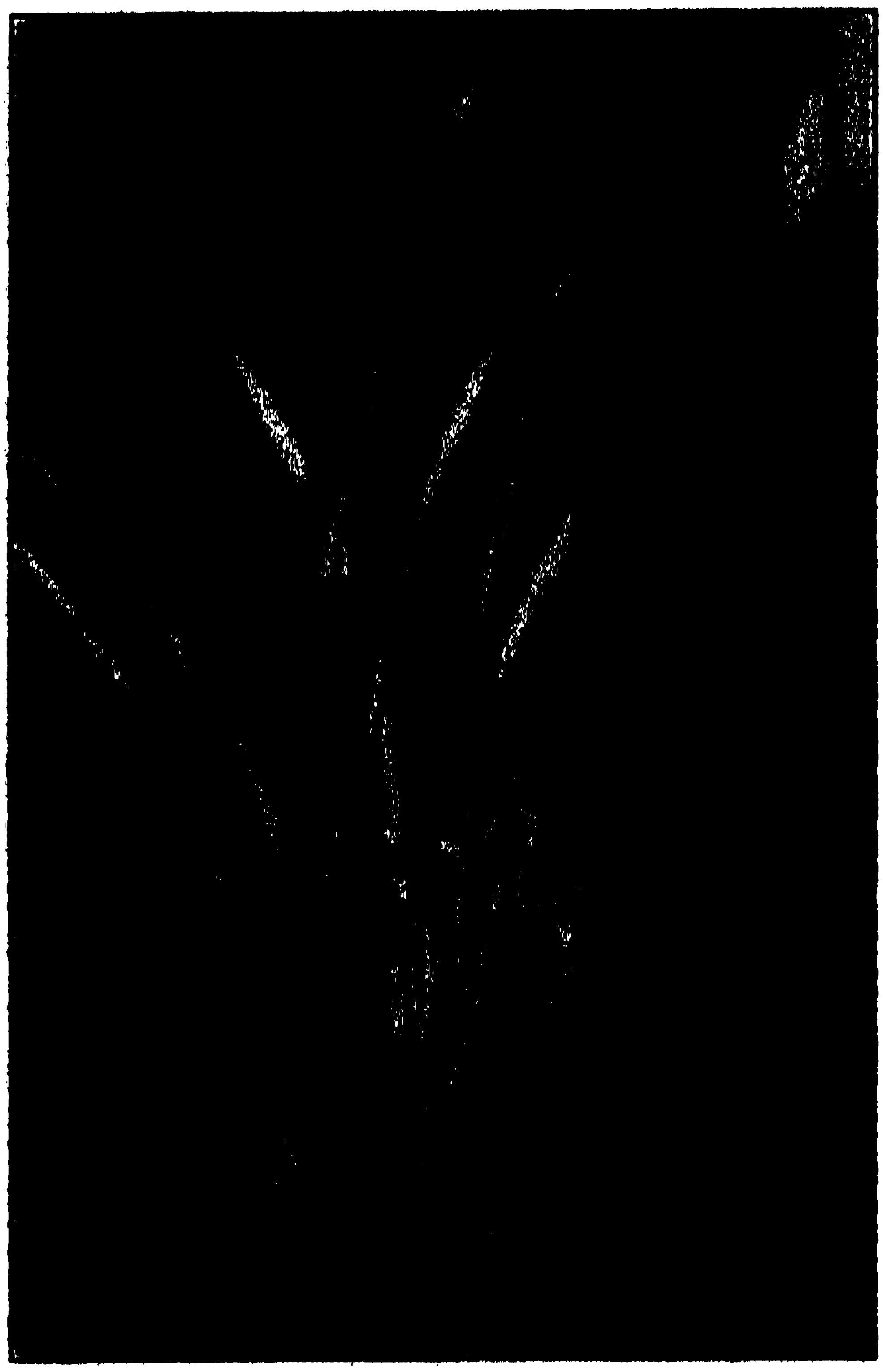
with a scattering of houses at the summit of the scenic railroad climb from the port of Santos on the Atlantic to São Paulo, and about an hour's run from the latter city. It has an elevation of about 2,400 feet, and the ridge on which it is located intercepts the moist breezes from the nearby ocean and causes an almost daily precipitation of water in the form of rain, mist or fog. The official records for the little village give an annual rainfall of 145 inches, with 161 days in the year in which rain was recorded. Judging from our experience, it is probable that on many of the days on which no precipitation was recorded in the rain gauge, the clouds must have hung over the ridge in the afternoon and from time to time enveloped the vegetation. We were fortunate in our afternoon since it actually rained but little, but the fog, when no rain was falling, collected on the foliage as well as on our garments. The type of vegetation showed that the air was almost continuously laden with moisture. On our earlier trip up from Santos we had remarked on the fact that at Alto da Serra, where we changed engines, was the only group of wooden houses we had seen in South America. Professor Hoehne told us they were made of wood in order to keep the dwellings drier in the moist climate. It is the constant moisture combined with the subtropical temperatures here—it is only a few miles south of the tropic of Capricorn—that affords optimum conditions for plant growth.

A short stone's throw from the railroad station at Alto da Serra, a winding path leads up into the biological station. Fuchsias, begonias and other plants familiar to us only in greenhouses bordered the pathway. Tree ferns were common as well as delicate filmy ferns (Hymenophyllaceae), which grow only where moisture is abundant and continuous. We stopped a moment for a view of the landscape looking down toward Santos and the ocean. Later in the afternoon, on our return, we saw from the same spot the clouds rolling up the slopes like smoke. Paths named after biologists who had visited the place intersect the reservation in various directions. These footpaths have been well planned to give access to the different types of vegetation within the station, and their excellent condition and easy grade were appreciated by the women of our party.

A WINDING FOOT PATH IN THE BIOLOGICAL STATION

SHOWING A YOUNG TREE FERN AT RIGHT AND A MOSS-COVERED BANK AT LEFT. PHOTO BY A. F. BLAKESLEE.

The station is six kilometers long by one and a half wide and includes in its nine hundred acres a wide diversity in



MAXILLARIA PICTA
A VERY INTERESTING EPIPHYTIC ORCHID FOUND IN THE BIOLOGICAL STATION. THE FLOWERS, SEEN TOWARD THE BASE OF THE NARROW LEAVES, ARE WHITE THICKLY SPOTTED WITH PURPLE. PHOTO BY F. C. HOEHNE.

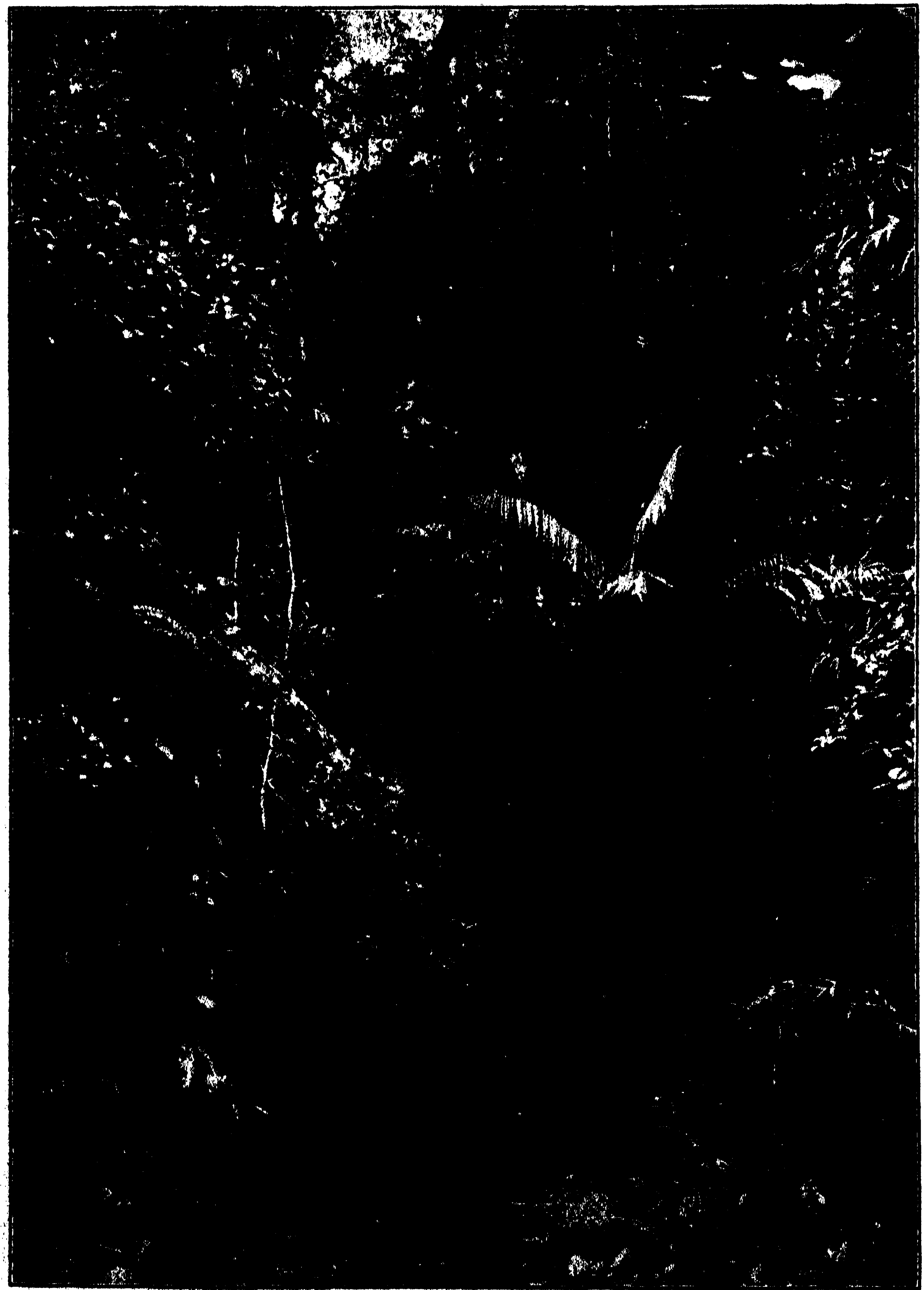
soil and altitude. In consequence, the flora is extremely varied. Open meadows as well as virgin forests are encountered within its limits. A wooden building affords a dwelling for the caretaker as well as a rest room and laboratory for visitors.

In his beautifully illustrated volume recently published on the Botanical Department of the São Paulo museum, Professor Hoehne has given some statistics regarding the species of plants which will afford an idea of the richness of the flora. Within the confines of the biological station there have been identified so far about six hundred species of trees and shrubs; thirty to forty species of Bromeliads; more than two hundred species of mosses and hepatics; about one hundred and fifty orchids; about fifty each of Melastomaceas and *Rubiaceas* and as many species of ferns; about a dozen different palms and a dozen species of Begonias; and some hundreds of species representing other less common families. Not only is the ground covered with vegetation, but the trunks and branches of the trees as well. A tree was pointed out to us on which twenty different species of orchids has been found growing, as well as an abundance of other epiphytes.

The orchids were of especial interest to one who was not familiar with them outside of conservatories. One species is so small that the whole plant could be included in a circle one centimeter in diameter—half the size of an American nickel. We saw growing on a trunk one moss-like orchid that was twice this size, but it had such minute flowers that we were obliged to use our pocket magnifying glass to make out its perfectly formed floral structures and to satisfy ourselves that it was in fact an orchid.

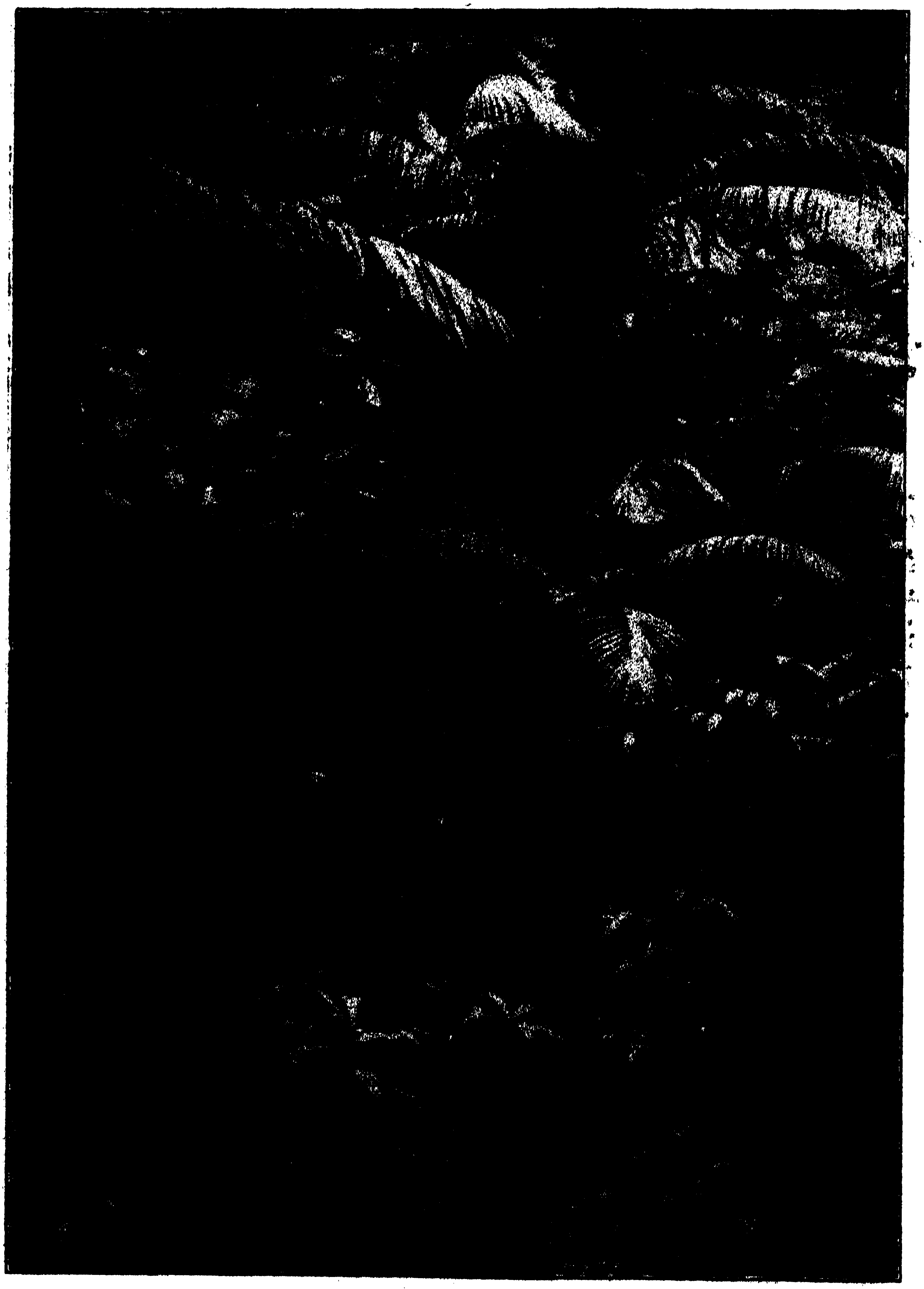
We can confirm the testimony of the much-travelled Belgian botanist, Professor Jean Massart, who writes that he knows of no station in the world so interesting as Alto da Serra. He adds that the reserves belonging to the famous Botanical Gardens of Buitenzorg in Java, which botanists have generally considered to have the most luxuriant tropical vegetation of the world, has a less varied flora.

It is not appropriate here to give a detailed description of this intensely interesting biological station. I wish merely to call its attention to travellers in South America who are interested in plants. It is my suggestion that, when they are at the famous snake farm at Butantan in São Paulo, they visit the nearby botanical building and make arrangements with Professor Hoehne or with some one of his associates for a trip in the morning to the biological station at Alto da Serra.



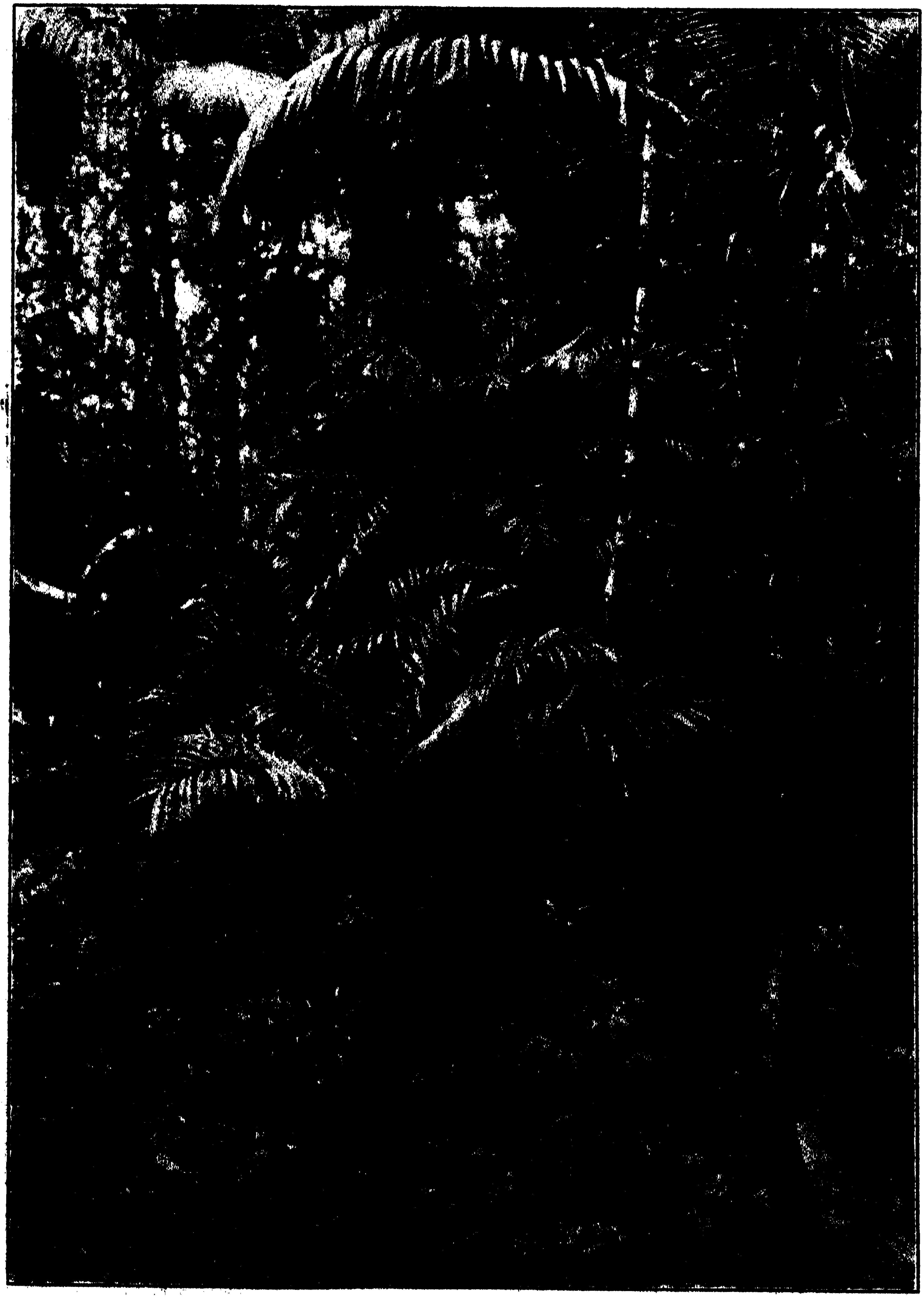
A VIEW IN THE VIRGIN FOREST

SHOWING THE COMMON "JUSSARA" PALM (EUTERPE EDULIS) SOMETIMES CALLED THE ASSAI PALM FROM THE FACT THAT ITS SEEDS ARE USED IN THE PRODUCTION OF A DRINK KNOWN AS ASSAI. THE LONG PENDANT ROOTS OF PHILODENDRON EXIMIUM, MORE COMMONLY CALLED "IMBE" ARE SEEN HANGING DOWN FROM THE LEAFY CANOPY AT THE RIGHT OF THE PICTURE. PHOTO BY F. C. HOEHNE.



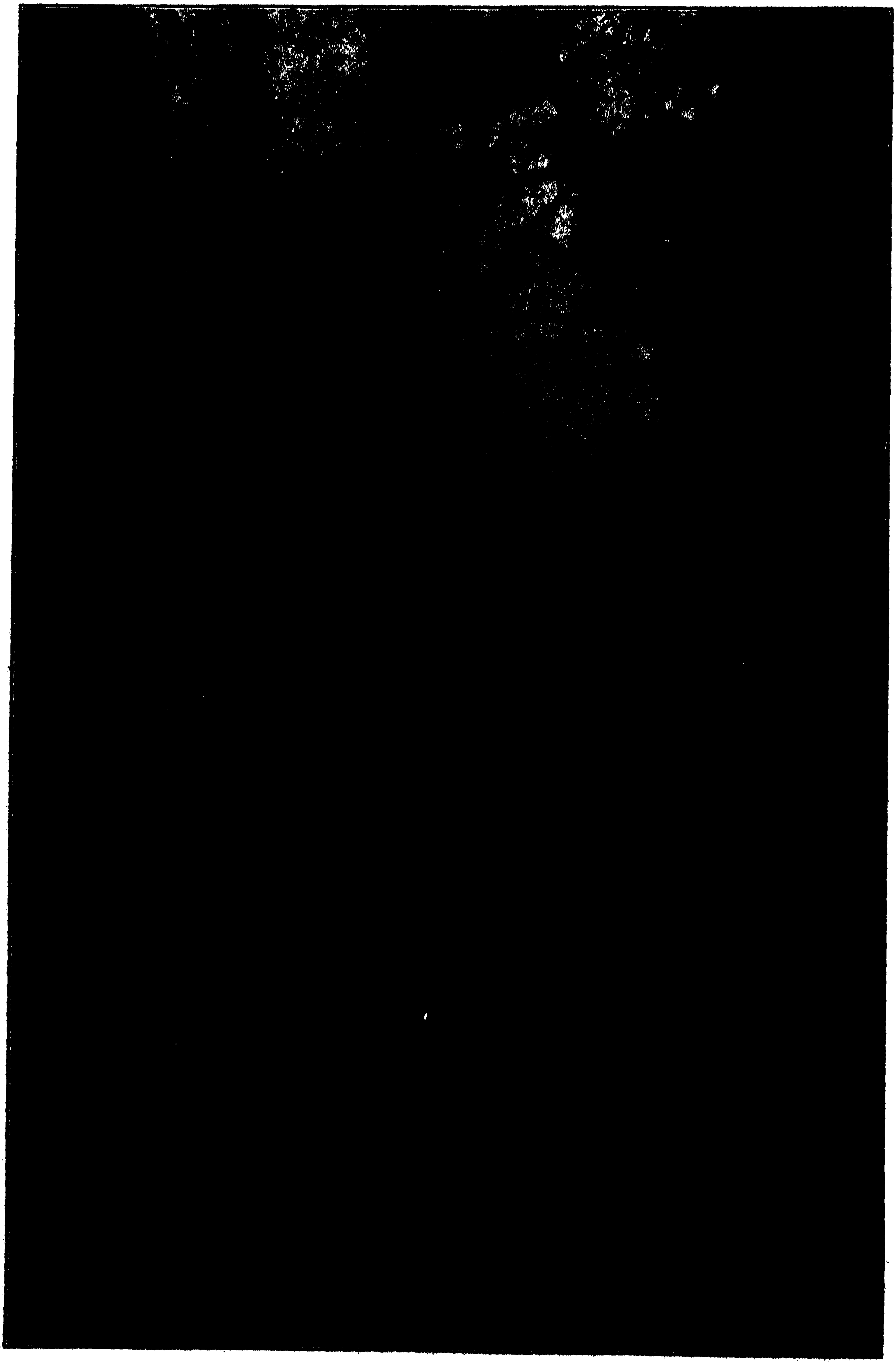
A BEAUTIFUL GROUP OF JUSSARA PALMS

IN THE PLACE WHICH HAS BEEN CALLED "PARK OF THE JUSSARAS." PHOTO BY F. C. HOEHNE.



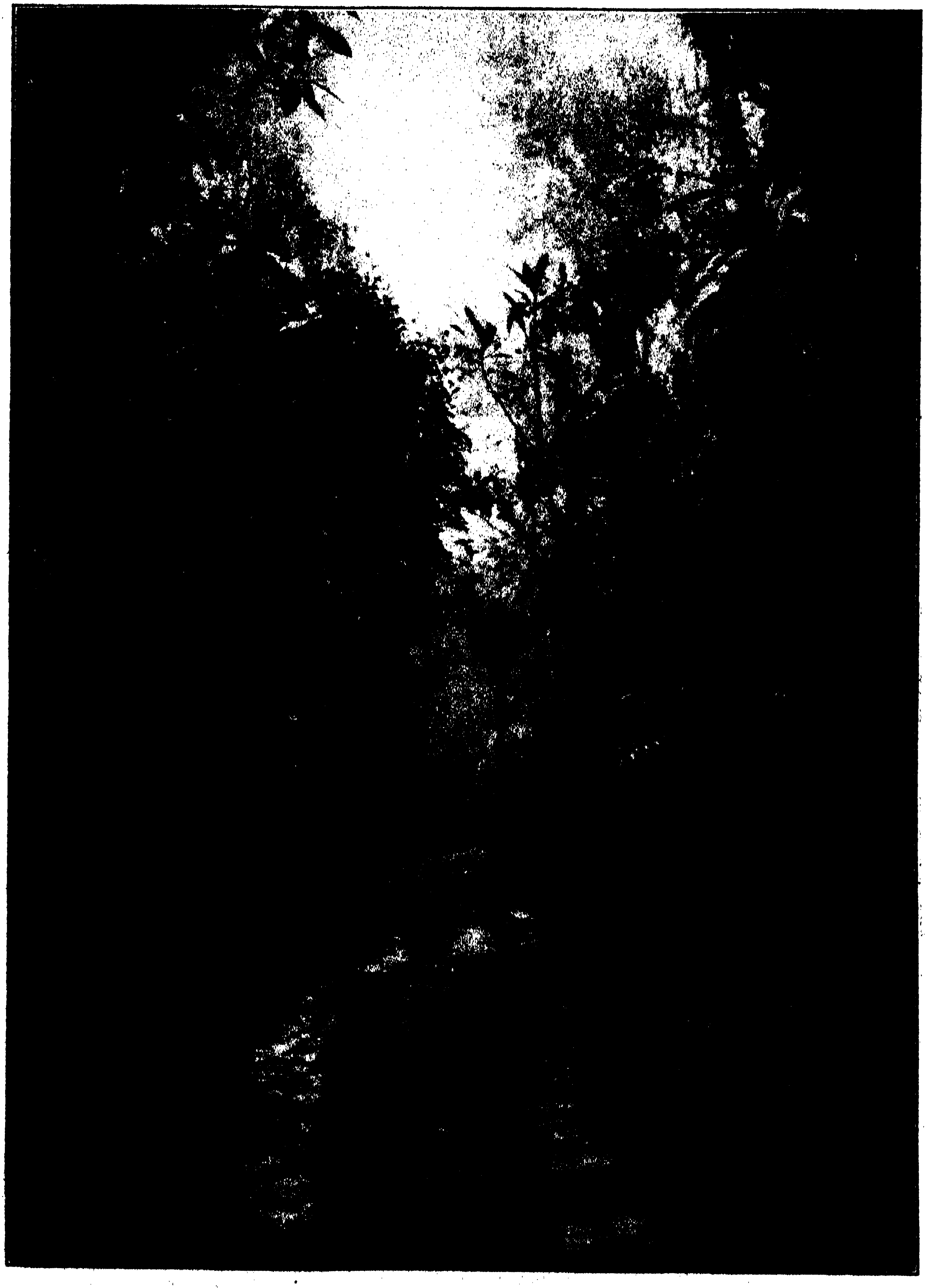
A GROUP OF GEONOMA PALMS (G. SCHOTTIANA)

THIS GRACEFUL SPECIES CALLED "GUARICANGA" OR "UBIM" IN PORTUGUESE, IS AN UNDERGROWTH FORM AND NOT LIKE THE TALL PALMS MORE FAMILIAR IN OPEN PLACES. PHOTO BY F. C. HOEHNE.

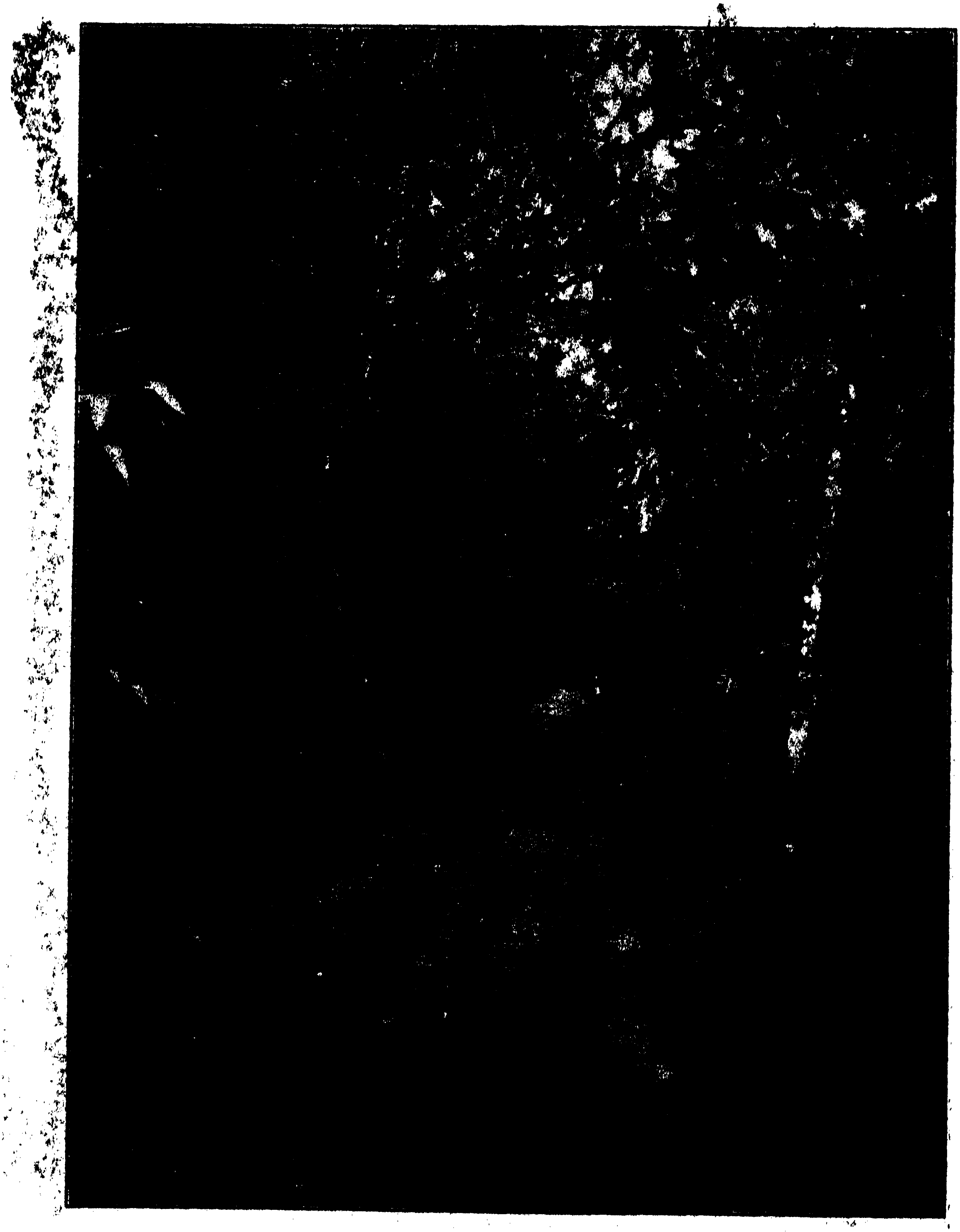


A VIEW LOOKING UP THE FOOT PATH "WASHINGTON LUIS"

NAMED AFTER THE PRESENT PRESIDENT OF BRAZIL. THE FOG IS ABOUT TO ENCIRCLE THE FOREST. PHOTO BY F. C. HOEHNE.

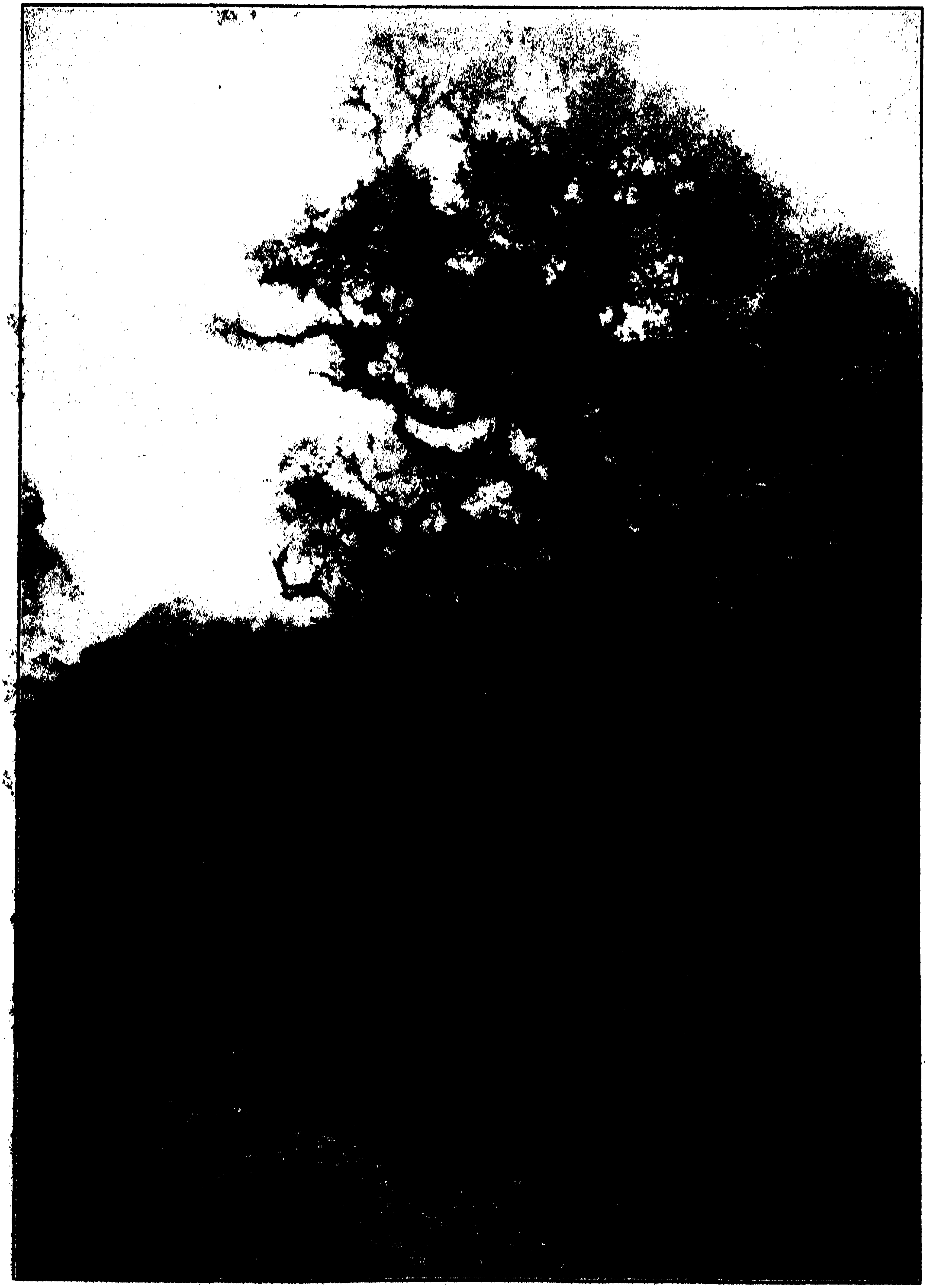


VIEW ALONG THE FOOT PATH "DR. FREDERICO VON MARTIUS"
THE FOG CAN BE SEEN ROLLING IN TO MEET THE OBSERVER. PHOTO BY F. C. HOEHNE.



TREES ARE SHOWN OVERGROWN BY ORCHIDS AND BROMELIADS

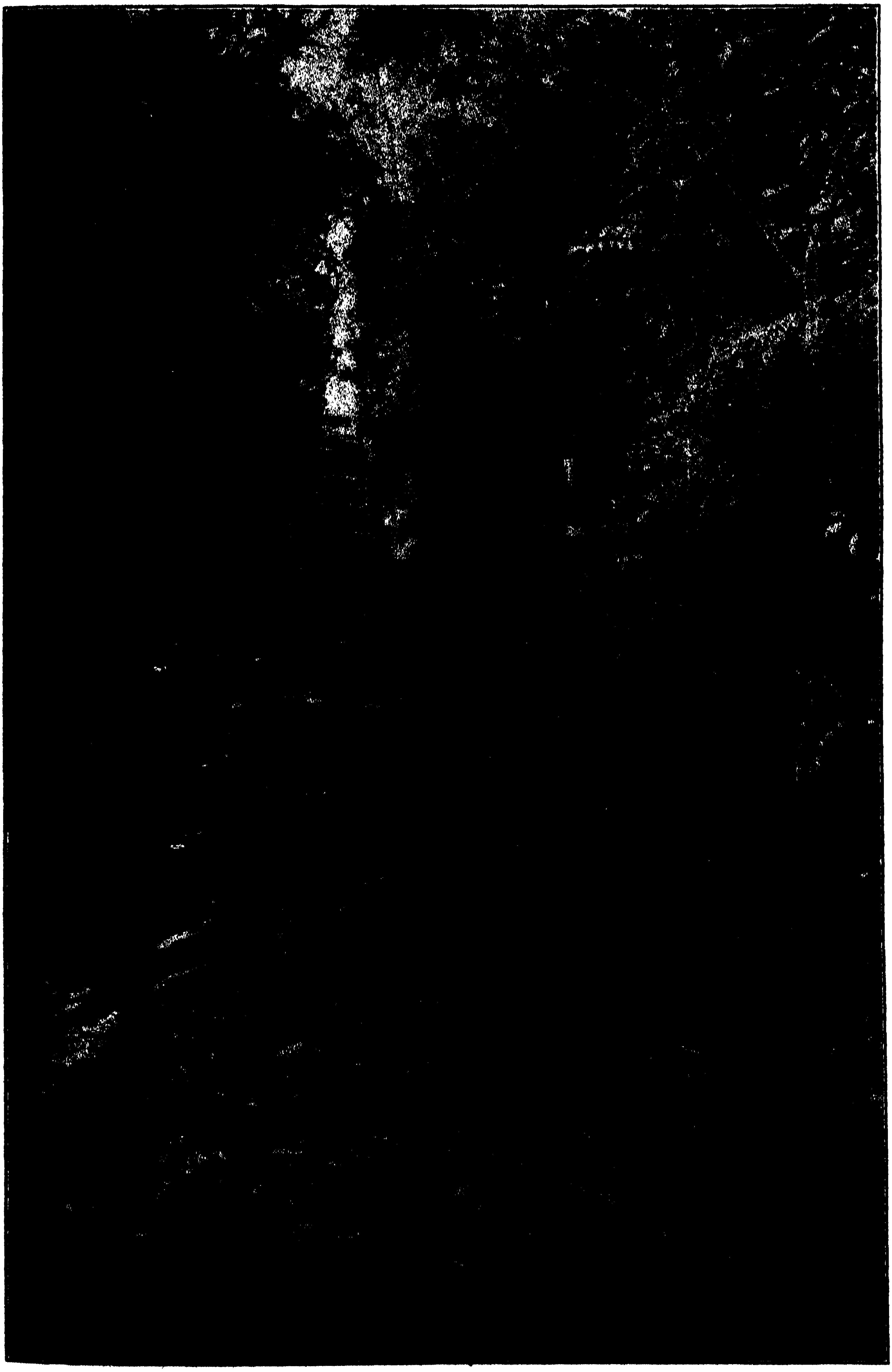
The surface of a trunk is often completely covered from bottom to top.
Photo by F. C. Hoehne.



AN OLD TREE

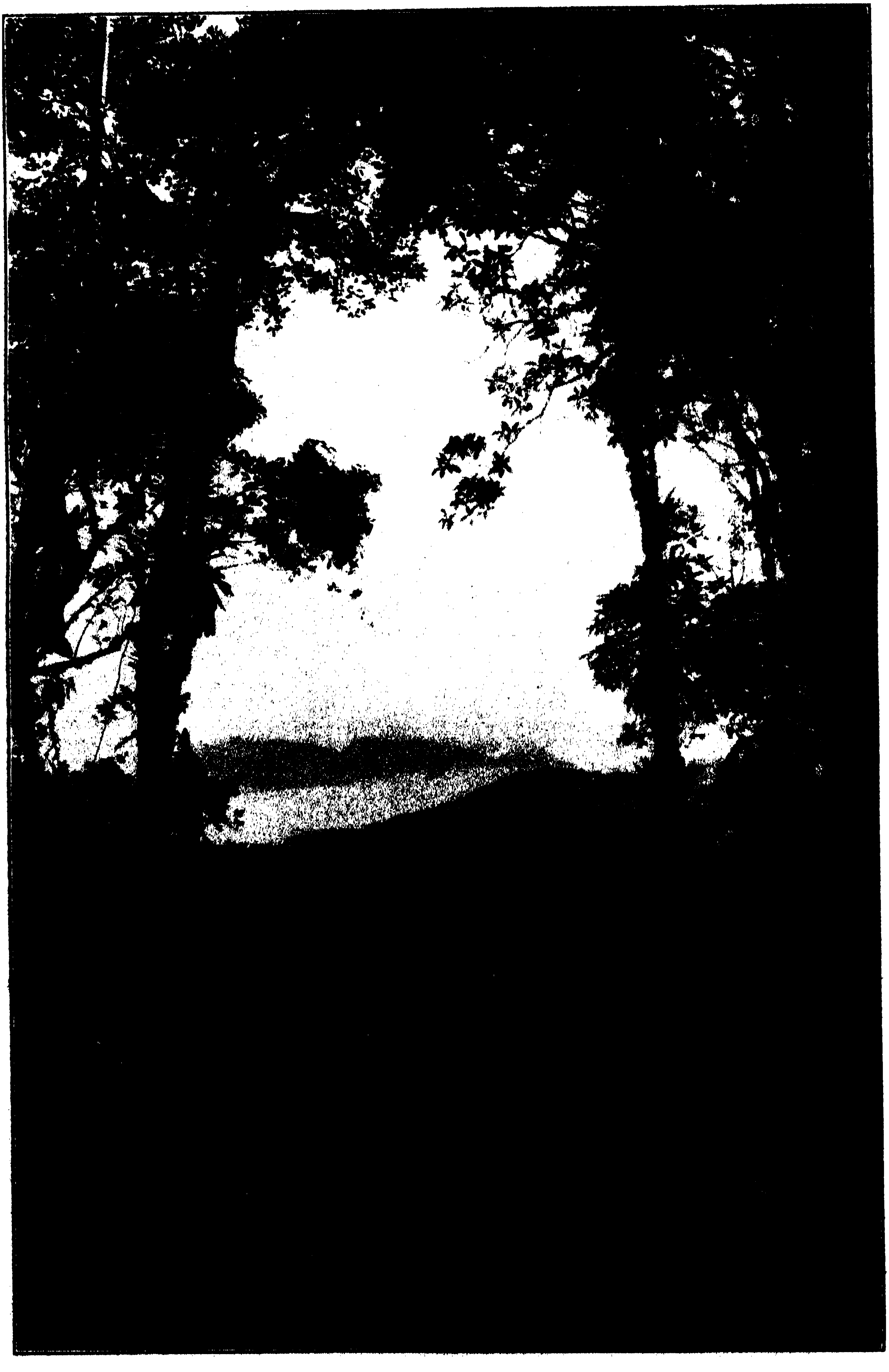
WHICH IS ACTING AS HOST TO MANY INTERESTING AND BEAUTIFUL ORCHIDS. PHOTO BY F. C. HOEHNE.

INTERIOR OF THE VIRGIN FOREST OF THE BIOLOGICAL STATION
PHOTO BY F. C. HOEHNE.



AN ASCENT WITH STEPS IN THE PATHWAY "WASHINGTON LUIS"

Along this pathway one may climb from a height of 600 meters (about 2,000 ft.) above sea level to an elevation of 900 meters (nearly 3,000 ft.). Photo by F. C. Hoehne.



A SCENE FRAMED IN TREES

FROM THE HIGHEST POINT OF THE PATHWAY "DR. ADOLPHO LUTZ." PHOTO BY F. C. HOEHNE.

THE GROWTH OF EXPERIMENTATION IN THE EARLY SCIENCES

By Dr. **EDWARD F. ADOLPH**

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TO-DAY experimentation is *the* method of science. It was not always so; indeed, it has been so for but a short span in the history of progress. Whence came this method, and what did it supplant? Other methods have in other ages been just as sovereign, and indeed experiment was once anything but orthodox.

At the outset we meet a large difficulty in describing just what we mean by experiment, and then a larger difficulty in describing what our predecessors in science meant by experiment. To some an anatomical dissection is an experiment, in fact, Vesalius is often called the first of the experimenters; to some the observation of those changes which occur as consequences of variations of nature constitutes experiment; to others a measurement obtained by the use of complicated laboratory apparatus is an experiment.

It might satisfy the requirements of science's present status to say that, in physical terms, every system is composed of and environed by a number of invariable factors and a number of variable factors. Any description which takes into account one or more variable factors is an experiment. This would include some of the mathematician's investigations as well as what nature presents to the pathologist.

But to Pliny an *experimentum* was a testing-out process. Thus, a test for the toxicity of the air in a well was to let a candle down into the well and see if its light went out. To the Roman of the decadent period, Hero of Alexandria, for instance, an *experimentum* was a secret of nature, such as the transmutation of metals; or sometimes merely a marvel of nature, as the annual overflow of the Nile. Later, to Philostratus, for example, an *experimentum* was an entertainment stunt, such as a sleight-of-hand performance. To William of Auvergne an *experimentum* was the manipulation of the strange instruments which the court astrologer, and sometimes the court jester, exhibited before the king. Thorndike[2] says that: "Throughout the period from Galen to Roger Bacon experiment meant only one thing, namely, the performance of magic. There was no implication of an attempt to get at causes."

It is necessary, therefore, in order to extract information of scientific significance from early sources, to disregard what Seneca or Pliny *called* an experiment and to discover what experiments, in *our* sense, were actually performed. One must not be disappointed to find that those who performed these experiments were not proud of them; indeed, experiments were regarded as such unimportant products of material manipulation that the records made of them were fragmentary and incidental.

In past ages the scale of values and the intellectual tradition were in sharp contrast to those which have produced the present-day universality of experimentation. The contrast shows, for one thing, how efficient and effective a factor in creative work is the apparently harmless philosophy which forms the background. Animistic theology, which seems to have constituted the earliest mental content of our race, implied that an understanding of nature came by revelation. Crudely put, the existence of immortal entities was the starting point from which the forms of earthly existence could be deduced. These were like the axioms in geometry; granted them, the rest was just reasoning and contemplation. It was dangerous to one's status in the community to ask whence came the axioms. The purposeful experiment, then, would be a doubt of an axiom; it took a heretic to perform it; no wonder he did not herald it as the introduction of a new method of progress.

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[2] Lynn Thorndike, "A History of Magic and Experimental Science." New York, 1923, Vol. 1, page 21.

Nevertheless, experiments were performed and made use of. In evaluating them it is always hard to tell whether one is reading too much or too little between the lines. Thus, the philosopher Pythagoras (582–489) is credited with discovering the numerical relations of auditory pitch. Gomperz believes that in this Pythagoras made the "luckiest hit in the history of science." But in the estimate of Allbutt,[3] "Pythagoras seems to have initiated his experiments for the very reason that subjective standards were variable and fallacious." Boethius is the source of the story that Pythagoras, listening to the clanging of hammers on a smith's anvil, noticed that some combinations of blows made harmonious sounds, others did not. Pythagoras seemed to find, on examining the hammers, that neither their shape nor the force with which they were struck was responsible for the pitch, but only their weights. Upon this hint he went home and stretched strings of a uniform kind to different extents by hanging weights on them. The notes emitted by these strings when struck were said to bear simple relationships to the weights on them. But as a matter of fact, neither the weights of hammers nor the weights or tensions upon strings are proportional to the frequencies of vibration; Boethius' tale would therefore not account for Pythagoras' discovery. The correct numerical relationship would be given by the relative lengths of strings placed under uniform tensions. The stringed musical instruments of Pythagoras' day undoubtedly used this principle; perhaps Pythagoras had the scientific curiosity to measure the strings.

With Socrates and Hippocrates came the first philosophic demonstration that some knowledge, at least, was to be derived by induction from facts, rather than by deduction from axioms. Socrates' (470–399) material was gathered chiefly in the field of ethics, and it is very difficult to find any instance where a decisive experiment (in the modern sense) was performed by him. But in the works of Hippocrates' (460–370) school are recorded several experiments which to the modern ear sound not only prototypical but intentional.

Neuburger[4] describes an instance where Hippocrates made use of nature's experimental material. The father of medicine says that in the case of suicides section of the windpipe produces a loss of voice; from this fact it is deduced that voice is caused by resonance of the air inside the windpipe. A more intricate experimental procedure is given as proof of the competence of the semilunar valves. "If a heart be taken out of the body, and of the two valves, one be supported and the other allowed to hang free from the walls, neither water nor air impinging upon them will be able to effect an entrance into the heart."

In the brief treatise "On the Heart" Hippocrates[5] describes a demonstration that, in drinking, some of the fluid passes into the windpipe, and, as he thought, goes to the lungs. "If one administers water colored with ochre or vermilion to an animal almost dying of thirst, preferably a pig, and while it is drinking one cuts its throat, he will find the windpipe colored by the potion." The work "On the Heart" is not considered as genuine among those works credited to Hippocrates. Certainly, however, it was written in the Coan school, at some time before the Roman period.

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[3] T. C. Allbutt, "Greek Medicine in Rome." London, 1921, page 96.

[4] Max Neuburger, "History of Medicine." Translated by Ernest Playfair. London, 1909, Vol. I, page 152.

[5] Hippocrates, "De corde." Editionem curavit D. C. G. Kühn. Lipsiae, 1825, Vol. XXI, pagina 485.

But Socrates and Hippocrates put no true reliance upon experimentation; it was not recognized as a method of discovery, and their followers almost abandoned it. Plato indeed was interpreted for twenty centuries to hold that experience was of no value. On the other hand, Aristotle (384–322) practiced the art of observation and, at least as far as he was himself concerned, laid the foundations of empirical science. We find almost no record of a real experiment, however, in the whole of the works of Aristotle, unless it be that the opening of hen's eggs on successive days of incubation be an experiment, with time as the variable. It depends on one's latitude in using the designation of experimentation. Thus Allbutt[6] says that "Aristotle made occasional experiments; for instance, on the alleged immunity given by marjoram to tortoises which were thereby enabled to eat snakes with impunity." In this experiment the peripatetic evidently omitted to test control animals. It is interesting to note in this connection that the introduction of the inductive method by Socrates and Aristotle also initiated specialization in intellectual work. For empiricism was a recognition of the failure of Thales, Anaxagoras and others to show the connection of their axioms with common sense.[7]

A certain pupil of Aristotle who was a physician, named Menon, wrote a comprehensive treatise on the history of medicine which is now completely lost. The treatise was used as an authoritative text for some centuries, and certain fragments, supposedly from a student's notebook of 150 A. D., indicate that the treatise contained descriptions of some actual experiments. In particular, the influences of feeding, upon the losses and gains of weight by the body, are mentioned. This is notable as the first recorded attempt at exact measurement in physiology, and an early anticipation of the use of the balance by Nicolaus of Cusa and Sanctorius.

Archimedes (287–212) is sometimes pictured as the prototype of the experimenter. Whether or not we should consider him so depends upon whether we look merely at his results or whether we look at his method of work. For Heath[8] has shown that Archimedes' levers, pulleys and water-screws were used by Archimedes as ocular demonstrations of his deductions, and not as the starting point for inductions. His so-called experiments, those that impressed his contemporaries, are almost without mention in his own work. Thus in his treatise "On Floating Bodies"[9] there is no mention of the determination of the specific gravity of gold in the famous testing of the crown. Archimedes experimented, but not inductively.

This introduces the generalization that every science seems to exhibit a cycle in the methods by which it does its work. At first there is speculation, in the second stage observation and thirdly experimentation. These three processes are inductive. Once generalizations have been reached the science passes into the final or deductive stage. All the stages of induction were very brief in the case of geometry; so brief that even

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[6] Allbutt, *op. cit.*, page 129.

[7] W. Whewell, "On the Philosophy of Discovery." London, 1860, page 33.

[8] T. L. Heath, "The Works of Archimedes." Cambridge, 1897, page xiv.

[9] Heath, *op. cit.*, page 258.

Euclid failed to realize that his axioms resulted from this process. Yet in the work of Pythagoras it seems fair to conclude that geometry was in an observational stage. We might even consider as experimental arithmetic the arrangements of spaced dots which the Pythagoreans used.

In other sciences induction has been a much more prolonged process; but many fields of physical science are now largely deductive, while in physiology there is yet hardly anything from which to deduce. In causal morphology and pathology the experimental stage has barely begun, while in anthropology observation has barely succeeded speculation.

So at any one time we may find sciences in all stages of evolution. Also we may judge of the completeness of various sciences by tracing the relative durations and complexities of the various stages in their history. And this leads to the suggestion that here lies a value in the history of science which is only beginning to be recognized: from its study it is possible to piece together the elements of a science of science.

The biological sciences, as well as the physical sciences, relied upon nature's experiments for many centuries. As astronomers like Claudius Ptolemy were able to induce the principles of light and motion from examination of the heavens, so biologists such as Pliny and medical men such as Oribasius were able to generalize and systematize their facts from the comparison and the pure observation of what they *happened* to see. Seneca, diligently digging in his vineyard, found that no rain was ever so heavy as to moisten the earth to a depth of more than ten feet. That might have been an experiment, had he set himself a question before he dug, but actually he drew merely upon his general experience when he concluded that therefore "all the moisture is consumed in this outer crust and descends not to the lower part." He laid no building stone for geology, after all.

There is some indication that experiments were actually performed in the Alexandrian schools of medicine. One need not refer to the oft-quoted test by which Erasistratus (350–280) diagnosed, and the diplomacy by which he secured a cure for, the lovesickness of King Ptolemy's son.

Erasistratus kept some chickens in a jar, weighing them and their excreta at intervals. He weighed them after feeding, and after digestion was completed. During starvation he found that more weight was lost by the birds than was contained in the excreta. This he said was due to insensible excretion. It is not clear whether this experiment was related in idea or in act to the experiment accredited to Menon.

Erasistratus seems to have understood the valves of the heart, and to have correctly stated their action. If not experimentation, this bit of physiology at least involved an amount of intentional observation worthy of original investigation. It often seems as though that which is an experiment in one age is merely a controlled observation in the next; there is a factor of boldness which is present only the first time. Perhaps to Herophilus the greatest experiment was when he cut into his first human cadaver.

In the works of Pliny (23–79), that omnivorous scavenger of fact and fiction, we find several instances of well-recognizable experiments. One that is remarkably modern is the marking by an ancient "scientist" of a dolphin's tail, in order if possible to determine its length of life; and in fact Pliny says that this experiment was completed some three hundred years after its inception by the finding of the dolphin. Another is the sinking of a well, to prove by its complete illumination that the sun casts no shadow at noon of the summer solstice. This procedure strangely reminds one of the troublesome experimental method by which roast pig is said to have been devised. A still less modern experiment is the casting of a man into a pit of serpents at Rome to see if he was immune to their stings. Pliny also credits the physicians of his day with a great aptitude for experiments, for he says in quite modern vein that the doctors learn at our risk and gain experience through our deaths.

It is safe to say that Greek and Roman science was successful wherever the deductive method was sufficient. An early philosophy of inductive science is contained in the works of the astronomer Claudius Ptolemy. He says that to avoid errors one should repeat accurate observations at long intervals. Further, from the observations one must construct the simplest hypothesis consistent with the facts. This marks a new epoch of objectivity when compared with the stolid deductive universe of Anaxagoras or with the later use of experiment to illustrate the value of reasoning by Archimedes.

We now come to Galen (130–200). In his works are clear descriptions of several first-class experiments; and we are certain that the procedures described were actually carried out by him instead of being merely projected, as in the case of many earlier authors, and that they were original with him. One of his most significant experiments was the refutation of Erasistratus' teaching that the arteries contained air. Galen bound at both ends the femoral artery of a freshly killed animal, and showed that its lumen was filled with blood and had no room for air.

Galen was not the first biologist to be called upon to give public demonstrations of experimental phenomena. But it was under such encouraging circumstances that he showed the connection between the brain, the voice and the breathing. Galen while still a student had become interested, in the sense of a modern investigator, in the movements of the chest in breathing. He it was who first realized that the diaphragm and intercostal muscles were alone responsible for the movements of the lungs. He discovered that by cutting various nerves and various parts of the spinal cord he could tell which nerves initiated the movements involved.[10] This required a great many trials and led him to systematically cut all the nerves of the chest. While doing so he happened upon a definite response to the cutting of the recurrent laryngeal nerve. Walsh[11] has reconstructed for us just how the experiment must have proceeded. "The pig was tied on the table without an anesthetic, and only kept intermittently from squealing by the hardy hands of a slave. The recurrent laryngeal was cut, and in a dramatic fashion the squealing stopped instantly."

It appears that during a number of years Galen carried on intermittently his truly great experiments investigating the distribution of nerves from the brain and spinal cord. He sectioned and hemisectioned the cord at various levels. In this way he demonstrated that the chief nerves arose in the brain. At one stroke Galen devised the method for the investigation of the central nervous system by which has been derived all our detailed knowledge of localization and paths; and single-handed he advanced neurophysiology to the place where it stood until the work of Magendie and Bell about 1810.

The presence of real experimental technique in Galen's work is illustrated by his improvement of Erasistratus' diagnosis of love-sickness. A girl, who showed no dangerous symptoms, was found to quicken her pulse when some one came in from the theater and said that he had just seen Pylades dance. Next day Galen arranged a control by having some one come in and describe how Morphus had danced; the pulse did not change. On the third day Pylades' name was again mentioned, and again the pulse quickened. One gains an impression of Galen as a great poser; one who found his science an undeveloped means of making a startling diagnosis or an awe-inspiring demonstration.

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[10] Claudius Galenus, "De anatomicis administrationibus." Editionem curavit D. C. G. Kühn. Lipsiae, 1821, Vol. II, paginae 675, 842.

[11] Joseph Walsh, "Galen's Discovery and Promulgation of the Function of the Recurrent Laryngeal Nerve." *Ann. Med. Hist.*, Vol. VIII, 176–184, 1926.

Among the isolated instances of experiment previous to Galen, which have been enumerated, it is evident that most were purely incidental. But, at least, Galen and his predecessors had what Pasteur labelled the prepared mind. Alchemy presents a long history of hit-or-miss "experiments" from which almost nothing of scientific value was derived. Of deliberate experiments for scientific purposes, the best examples are those of Archimedes; but he merely did the experiments for the sake of showing the correctness of his deductions. The deliberate experiment which really bore scientific fruit was probably quite without precedent in any field of knowledge when Galen sectioned the spinal cord. Thus through several centuries we might trace the evolution of definiteness in experimentation.

It may be some comfort to those who can still remember the first heralded successes of exact experimental methods in some of the biological sciences, such as zoology and botany, to realize that biology really commenced to experiment before any other science.

But the subsequent fate of biological experimentation has not been so picturesque. One finds discussions of experimental method in the compilations and commentaries of Galen's successors from Paul of Aegina to Adelard of Bath. Experimental method was something to be pigeon-holed and labelled, like the syllogism in logic. Roger Bacon relegated experimental science to a separate field of knowledge; what we should call applied science. To him, as to Archimedes, experiment was the result of deduction. This is evident in the passages where he put forward his fine projects for microscopes and artificial rainbows, which have been interpreted to represent his actual accomplishments.

Nevertheless, as Allbutt[12] has said, "Roger Bacon proclaimed, what even Aristotle scarcely comprehended, that casual experiments are but curious incidents, not indeed in divination of remote or primary causes wherein effects are to be found, nor again in searching behind phenomena for their essences or formative substances, but in detecting and concatenating by the experimental method the series in which they occur."

Meantime, experiments of a systematic character were carried out, very probably, in the field of optics. These start with the studies of refraction by Cleomedes, and the analysis of reflection and visibility by Ptolemy. This was the one field to which the Arabs seem to have contributed true experiments, represented in the writings of Albategnius, Alhazen and Algazel.

With the return of learning to Europe the records of experiments increased in number. Gradually the isolated experiments of the awakening age come to have a meaning; and one can trace their gradual evolution, however incidental their character, in the work of Albert of Cologne, the Holy Roman Emperor Frederick II, Nicolaus of Cusa, and others. Despite the brilliant attempts at experiment by Leonardo da Vinci, Andreas Vesalius, Bernard Palissy and Bernardino Telesio, it remained for Galileo Galilei and William Harvey, only three hundred years ago, to combine the practice of experimentation with the recognition of experiment as a sovereign method of systematically answering questions.

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[12] Allbutt, *op. cit.*, page 501.

THE SOLID GROUND OF NATURE[1]

By Dr. PAUL R. HEYL

BUREAU OF STANDARDS

AN ancient Greek legend tells of three brothers who visited the oracle at Delphi. Why they went there we are not told. Possibly they went into the temple "for fun," as a party of young people to-day might stop in at a gypsy camp on passing to have their fortunes told. But there they were, three handsome youths, standing in awed silence before the Pythoness, that mystic priestess, waiting for her to speak.

The priestess chewed the leaves of the sacred laurel and drank of the water of the underground stream; then seating herself upon the tripod she gazed steadily at the youths and said: "To one of you shall be given riches and honor, power and glory."

The young men looked at each other, the unspoken question in their eyes: "Which?"

The Pythoness bent forward on her tripod and inhaled the mephitic vapor that arose from a fissure in the earth. The trance was rapidly coming on her and her utterance became fainter, but before losing consciousness she muttered: "To him who after his return home shall first kiss his mother."

The young men were very silent on their homeward way. As if by tacit understanding the two older ones fell a little behind their younger brother. Between the older youths there was scarcely a year's difference, and no perceptible physical advantage in either. They eyed each other furtively for a time, and then the older spoke.

"This should lie between us." The other nodded slightly.

"*He* is not to be considered." Again a silent nod.

"Shall we leave it to Dame Fortune? Shall we draw lots?" A third nod, and the two walked in silence for some time. In the mind of each was the same thought—that if fortune failed him he would make a last desperate appeal to force.

The youngest brother walked on, deep in thought. Suddenly he raised his head and quickened his pace. Their home was in sight. His brothers behind him broke into a run. The younger brother reached the gate first, but, apparently by accident, stumbled and fell. The others leaped over him and sped toward the house. But the younger brother as he lay prostrate kissed the earth, that great mother of us all.

No race has ever surpassed the Greeks in their keen sense of oneness with nature. In this legend we see clearly brought out the idea that he who wishes to prosper and go far must recognize this close relation and pattern his life by it. Such a one will in the long run triumph over force and fraud, over human scheming and machination, for as Wordsworth tells us:

> To the solid ground
> Of nature trusts the mind that builds for aye.

I am speaking to scientific men and women, and I do not need to point out how well this line expresses the mental attitude of the scientific worker; how the answer of nature to experimental question is for all of us as the decision of the Supreme Court, the ex-cathedra utterance of infallible authority. All students of nature, whatever their special field, are agreed in the acceptance of this fundamental principle. We all trust nature as the solid ground beneath our feet.

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[1] Published by permission of the Director of the National Bureau of Standards of the U. S. Department of Commerce.

But while nature is one, and her students are at one in their complete loyalty to her, these students group themselves, broadly speaking, into two classes: those who study only the physical aspect of nature, the astronomers, the geologists, the chemists and the physicists, and those who include in their view the phenomena of life, the paleontologists, the biologists, the physiologists and the physicians.

The division between these groups is marked by one of the very few sharp lines of demarcation to be found in nature: the distinction between the animate and the inanimate. Other apparently sharp lines there have been in the past, notably the distinction between organic and inorganic chemical compounds; but with the advance of our knowledge these have disappeared, leaving the life line as perhaps the only one which can still be regarded as tenable. It may be that in time this too will disappear, but for the present it stands unassailable.

The aspect which nature presents differs markedly as we view her from one or the other side of this line. To those who have eyes only for the inanimate she presents a certain definite appearance; to those who study the manifestations of life her aspect is quite different; while to the philosopher, whose aim it is to view all possible sides of a question, nature's aspect is perhaps the most interesting and instructive of all. Let us look at nature through the different glasses worn by these three types of students.

As the student of the physical side of nature goes farther and farther with experiment and observation there grows within him a deeply rooted feeling of satisfaction which is the all-sufficient reward for his devotion. Man may prove false, but to nature he may trust for aye. For this feeling of satisfaction several contributing causes may be assigned.

The first is the conviction, confirmed by every new experiment, that in the last analysis nature is reasonable. Her ways of working as we uncover them are found to be throughout consistent with the laws of thought. She never demands of a student that he subordinate his reason; she rather appeals to it. True, he learns from her to think more accurately and broadly as he learns to grasp more and more of her complexity, and he realizes that all that which he has learned or can ever hope to learn is perhaps but an insignificant fragment of nature's complete structure; but his feeling of satisfaction becomes the deeper as he reflects that whatever may remain unlearnable this much has become plain; that he himself is a part of nature; that her laws are his; that in learning the language which nature speaks he is but learning his mother tongue, beside which the Babel of confused philosophies which man has affected in all ages is but as infantile prattle.

A second quality of nature which contributes to the satisfaction which she imparts is her perfection. Nature, from the physical point of view, is our ideal of a perfect machine. The revolution of the earth on its axis is our ultimate standard of time by which the most perfect clocks must be corrected; and if there are indications that even this motion is being very slowly retarded it is from some other standard furnished by nature herself that we are able to verify this fact. As a perfect straight edge nothing of human construction can hope to equal the path of a ray of light. Even though fire should destroy or thieves break in and steal all the meter bars in existence, this standard of length could be reproduced from a light wave. Efforts to scatter or diffract X-rays by the most finely ruled gratings that could be made were failures; only when recourse was had to the much more finely spaced structure provided by nature in crystals did this become possible. Nature is the envy and the despair of the instrument maker.

Sir John Herschel speaks of the perfection and uniformity of the atoms, comparing them to manufactured articles. True, his concept of the atom was not that which we have to-day, yet in its essentials his comment still holds good; and with the complex nature of the atom as we now understand it this uniformity and perfection are but the more remarkable.

A third quality is ease of working. Perhaps this appeals most strongly to the mathematician or the astronomer. By means of the most powerful methods known we can scarcely attain an approximate solution of the problem of three bodies, yet this and far more complicated problems are daily and hourly handled by nature without the slightest hesitation in the motions of the heavenly bodies and in the atom. The terms "simple" and "complicated" seem meaningless to nature. Infinite is her grasp; multiplicity of conditions is to her as nothing. The machine, however loaded, works without creaking. Moreover, nature's laws seem to have a way of executing themselves without needing enforcement. You may have been fortunate enough to have been a pupil of one of those rarely gifted teachers who seem to manage without effort. Not a word is required. Her mere presence suffices. And so Dame Nature, like the catalyst of the chemist, brings about the reaction without perceptible exertion.

Perhaps the most striking illustration of this ease of working is found in the formation of crystals, especially when this takes place instantaneously from a supersaturated solution. At one moment there are billions of molecules milling about among one another at random in a disorganized, liquid condition; at the next, order and discipline prevail. Each molecule has found its proper place and has taken it with accuracy and rapidity.

Just how difficult is this task can best be understood by trying it. During the second Jubilee of Queen Victoria one of Her Majesty's ships of war, stationed at Alexandria, staged an impressive performance in honor of the occasion. The ship lay at anchor at such a distance off shore that a network of ropes hanging over her side was invisible. Her crew, in holiday white, lined the rail. At the signal of a whistle all was activity. The watchers on shore saw a multitude of white specks swarm over the rail and down the ship's side. A few seconds of confusion, then quiet and order. The specks ceased moving; the ship's guns boomed out the royal salute, and there, outlined against the gray side of that symbol of Britain's sea-power, the watchers read the words: "God save the Queen!" formed by the white-clad bodies of her loyal subjects.

This feat was doubtless difficult enough to require much practice, yet compared with what nature accomplishes in the formation of a crystal it is quite simple. Each sailor had his allotted place and went to it in an orderly and prescribed fashion. But suppose there had been no allotment of positions, and the thing had to be done on an interchangeable basis, a man to every place, but no particular man to any definite place. What confusion and delay would have resulted! Several men would make at once for the same position; another position, equally important, might be neglected. Yet this is the task which molecules have to accomplish in crystallizing. No place is reserved for any particular molecule. The whole process may be repeated as often as desired with a different permutation of the actors and in an incredibly short time.

A fourth and no less remarkable quality of nature is the permanence which she frequently exhibits on her physical side. Maxwell, in the article "Atom" which he wrote for the ninth edition of the Encyclopedia Britannica a generation ago, philosophizes on the permanence of the atoms as they were known in his day. He compares the active existence of an atom of hydrogen, subjected to the ceaseless round of chemical change in its environment, with the experience of living organisms, and points out that there is an essential difference between the two. The organism, as a result of change in environment, may in many generations undergo a process of development which we call evolution and finally assume a form quite different from that which it had at the beginning, while hydrogen, that may have been occluded billions of years ago in a meteorite and that has existed there ever since in monastic seclusion in an unchanging environment, is found on liberation to possess properties identical with those exhibited by its brothers who have lived the active life of chemical change for the same long period.

The discovery of radioactivity and the breakdown of atoms in no way invalidates the essential principle of this argument. In Maxwell's day it seemed that though molecules broke down atoms were permanent; in our time we go but a step lower: atoms may break down, but their constituent protons and electrons appear unchangeable.

Still a fifth quality of physical nature is economy of effort. This is called by the physicist the principle of least action and is illustrated by the fact that the path of a ray of light from a point in one medium to a point in another is that which requires the least time of travel.

Jointly these qualities present to us a picture most satisfactory to the mind. What nature does in her physical activities she does well, thoroughly, economically and always reasonably, though ever mechanically. To watch the physical working of nature is like listening to the music of a player-piano, which by its very perfection of time and execution, unimpaired by any fatigue due to ceaseless repetition, undisturbed by noise and chatter in the room, irresistibly suggests the unconscious, impersonal machine, rather than the sentient, fallible and perhaps temperamental living artist. A machine, impersonal, mighty in power, infinite in complexity and altogether overwhelming in its entirety, yet inviting our confidence by its reasonableness, its rationality as far as we are able to follow its workings—such is the aspect of nature as seen by the student of her physical phenomena.

But when we include the element of life in our study of nature her aspect changes. This, one may say, is only to be expected. Life itself is so transcendental a phenomenon, so different in kind from anything with which the physical student has to deal, that it is but reasonable to expect nature's aspect to differ when viewed from this new position. True enough; we expect something different, but something still possessing those qualities of perfection and ease of working which physical nature exhibits, perhaps exalted to a degree unsuspected before; but we are hardly prepared for that which animate nature actually shows us.

The first impression which she produces upon us is one of greatly increased complexity. Chemistry, it has been said, is nothing but complicated mechanics, a statement which the modern atomic theory, a microscopic edition of celestial mechanics, abundantly confirms. Physiology likewise we may perhaps regard as complicated chemistry, and psychology as complicated physiology. But mere complexity, of whatever high order, has no terrors in itself for the scientific student; it rather acts as a challenge. Were this all, the aspect which nature presents to the biologist would differ only in degree from that which she exhibits to the physicist.

But with life a new element demands

our consideration, for life is accompanied by consciousness, and in its train follow choice and free will, things so hard to reconcile with mechanical action that some have even argued that they do not exist. And what is still more serious, it is impossible for us, as nature has shaped and endowed us, to regard phenomena involving life and consciousness without introducing ethical considerations, the effect of which upon the picture is the most potent of all.

Living nature we find still reasonable. She violates none of the laws of thought. At times she holds rather tenaciously to logic when we, perhaps, would fain see her exhibit a little sentiment. But of the other qualities that contribute to the satisfaction of the physical student not one escapes without qualification.

When we examine animate nature for that perfection which was so prominent a quality in her physical aspect we are rather puzzled by what we find. We see much admirable perfection, almost perfect adaptation to environment; in other places nature seems to have grown weary in well-doing and, so to speak, skimped the job. Marvelous as is the human eye, exquisitely as it is planned, the practical execution of this plan impresses the critical student as having been rather incompletely carried out, the resulting product too often requiring the assistance of human skill. You will recall the saying of Helmholtz that if an optician were to furnish him an instrument containing as many defects as the human eye he would send it back to him with his severest censure. Here and in other instances animate nature seems to have abandoned that high ideal of perfection which was so characteristic of her physical aspect, and to be satisfied with something that is "good enough," that works after a fashion.

Again, we sometimes find living creatures encumbered with useless or even undesirable vestiges of organs which served at one time, it may be, some useful purpose, but which now lag superfluous on the stage of time. Such is the appendix in man, always a potential and often a real source of danger. "Why," asks the student, with the perfection of inanimate nature fresh in his memory, "why does not nature promptly remove the useless? What estimate would be placed upon the intelligence of a factory superintendent who would allow a discarded piece of machinery to remain in its place until natural decay removed it?"

Gone, too, is much of nature's ease of working. The machine creaks badly at times, especially in the newer and higher orders of life. Nothing is more important for the preservation of a species than the birth of a new individual, yet nature, in the human type, loads this important function with difficulty and danger.

As to the attribute of permanence, there is perhaps no quality so alien to life in all its manifestations. There may be found a few organisms which have retained their ancient forms for long geological periods, but for the most part the law of life is change; if not evolution, then degeneration.

It is not to be denied that this continual change has an attractiveness of its own for the biological student which may fairly be set off against the satisfaction afforded the physical student by the permanence which nature shows him. But this process of evolution, in the methods by which it is carried out, involves a very important consideration which never comes to the attention of the physical student: a quality which sets the ethical sense of man hopelessly at odds with Mother Nature, who has bestowed it upon him.

For nature is cruel or at least icily indifferent to the existence of suffering in her domain. She has no pity; mayhap she has given it all to man. From top to bottom of animate nature the weakest go to the wall. Her highest ideal seems to be that might makes right. And the particularly irritating feature of it all is that this procedure of hers is so coldly logical. As a working plan it is unassailable. Ethical considerations assume by comparison the aspect of impracticable theories.

Again, nature is wasteful, especially in the lower orders of creation. The physical principle of least action disappears completely. Millions of fish eggs are spawned and left to chance survival. Rain falls plentifully in the ocean when it may be sorely needed by living creatures on land. Notice that the element of waste in this process appears only when the life consideration is introduced. From the purely physical side the less rain on land the better, as rain on the continents effects their slow removal and ultimate disappearance. Nor does animate nature seek the shortest and most direct path to her ends. Her method of advance seems rather to be one of trial and error; she makes a thing, tries it and improves it for an eon or so, and then rejects it to try another line.

As man views nature in this aspect his impression is one of bewilderment. He wonders if he may trust his vision, if he sees aright, for there comes to him a strange suggestion: that he, a child of nature, because of this new ethical sense with which she has endowed him, is by just so much nature's superior. He disapproves, yet is helpless.

He looks back into the past of his race and sees that his ancestors were rather more closely in harmony with nature in this respect than he is to-day. Man has long since abolished attaint, but nature still visits the sins of the fathers upon the children. Human law no longer countenances the rack, but tetanus still tears the muscles of its victims from their very fastenings. Our law holds that it were better that nine guilty should escape than that one innocent should suffer, but nature's punishments are distributed with the blind impartiality of chance. It is considerations such as these that engender in the mind of man that strange suspicion of his own superiority which he half recognizes, half hesitates to believe.

But again he reflects grimly that every adolescent passes through a stage in which he thinks that he knows more than any adult in existence. Is this our own position? Is the human race intellectually still so immature as to exhibit a similar behavior toward Mother Nature?

Under the influence of such reflections the student of nature often keeps his own counsel, fearful lest an expression of opinion, however hesitatingly and modestly put forth, should place him in some such ridiculous light before his fellows. He keeps silence, waiting and hoping for clearer vision, and in the meantime in a sadly bewildered state of mind.

But the poets, to whom we scientists must so often turn when expression fails us, have not been blind to this aspect of nature, nor have they held their peace. Browning puts this answer into nature's mouth:

> ''See
> Or shut your eyes,'' said nature, peevishly.
> ''It nothing skills, I can not mend my case.''

And Tennyson complains

> That nature lends such evil dreams.
> So careful of the type she seems,
> So careless of the single life.
>
> So careful of the type? but no.
> From scarpéd cliff and quarried stone
> She cries, ''A thousand types are gone:
> I care for nothing, all shall go.''

There can hardly be a sharper contrast than that exhibited by these two types of students of nature, the physical and the biological, the one satisfied, the other bewildered. The cynic would say, perhaps, that both lack a proper view; the physicist does not see far enough to disturb him, and the biologist sees too much for his own peace of mind.

Now comes the philosopher, whose professed object it is to try to view as broadly as possible and in true perspective all different varieties of human thinking, and so far as possible to coordinate them. Here is an excellent opportunity for him. Has he anything to say that will be helpful in this *impasse* in which we find ourselves?

Yes, he has something to say; trust a philosopher for that; but as to its helpfulness, we may perhaps reserve our decision until we have heard it. And what he begins by saying does not seem to have much application to the difficulty. But philosophers have their own way of saying things, and must be humored if they are permitted to speak at all.

"You know," says he, addressing himself to the physical student, "that matter exists in three states, solid, liquid and gaseous. Warm up a solid. For a long time, perhaps, it remains a solid, its appearance and behavior changing by insensible gradations. The continual addition of heat is accompanied by a steady rise in temperature. But sooner or later a critical point is reached. Though the influx of heat is not halted the temperature stops rising. A new effect is produced, different in kind from any phenomenon previously exhibited. We say the body is undergoing a change of state and becoming liquid. In this new state new laws govern its behavior; its properties are radically changed. Yet it still remains matter, of the same chemical composition as before, in substance unaltered, though in behavior transformed.

"Soon the transformation is complete. The temperature again begins to rise as the influx of heat continues, and the properties of the liquid alter by insensible gradations.

"Eventually another critical point is reached, signalled by another halt in the rise of temperature. The liquid begins to boil, assuming again new properties. Yet in this new gaseous state it still remains matter, of the same composition as before, in substance unaltered, in behavior transformed.

"Now," continues the philosopher, "we may say that nature has been steadily warming up to her work since the beginning of things. Her past history has been one of change, of growth, of that development which we call evolution. Her future, if hindsight is to be trusted, will carry this evolution onward to a consummation of which we can as yet form no conception. And in this warming up process we may distinguish certain critical stages, not unlike the changes of state of matter. One of these critical points occurred when life first made its appearance, a totally new phenomenon superimposed upon inanimate nature.

"For untold ages no life was possible on this old earth of ours; it was too hot to permit it. But eventually, when conditions allowed, life appeared. With its appearance new phenomena present themselves. The machine-like character of nature loses its perfection and ease of working. New motives of action are recognizable; new combinations are possible. Yet living matter is but matter. In acquiring life it has not changed its fundamental character. In substance it is unaltered; only in its behavior is it transformed.

"Moreover, this transformation has not been complete. Living and non-living matter exist side by side, and will probably continue to do so. The physicist would call this the co-existence of two phases at one temperature, like a mixture of ice and water at the freezing point, each following its own laws and exhibiting its own characteristic properties.

"We may, perhaps, by poetic license think of the first beginnings of life as feeling strange and lonely in the midst of the non-living matter surrounding them, so different in appearance, in behavior. And perhaps we may imagine that the works and ways of non-living matter occasionally grated on the sensibilities of the living, and called forth the protest: 'Why are you so mechanical? Why not show a little flexibility occasionally?' But this protest, if any such were made, was wasted. "It is my ancient way," replied non-living nature, "the way I did for millions of years before you new-comers appeared upon the scene. I can not mend my case. Why not do as I do and be sociable?"

"But this is just what living matter will *not* do. Like white men in the tropics, it maintains its own standard of living among an overwhelming majority of an inferior grade of civilization. Millions of years have passed. Life is no longer a new-comer, a feeble colony, but has waxed mighty, and has become the outstanding feature on the earth's surface.

"And now," continues the philosopher, "we have come to a second critical point. Life has reached such a degree of development that a new set of phenomena is beginning to make appearance, something different in kind from anything that has been before; as different in its turn as was life itself compared to inanimate matter; something superimposed upon life as life of old was superimposed upon the non-living. And it is, appropriately enough, in man, the highest type of life, the flower of creation, 'the heir of all the ages,' that this new thing first makes itself manifest—a moral sense, an ethical feeling, which often finds itself as much a stranger in its environment as life must have felt among the crystals and colloids in which it began its existence. If we must find a single word to express this new quality, let us call it Soul."

The philosopher now addresses himself to the abashed and bewildered biologist. "Take courage," says he. "Your vision is better than you realize. Your face is turned toward the light, though for the present you fear to look at it, or can not bear its glory. Allow time for your sight to become accommodated, and then look boldly at what you see.

"You feel that certain aspects of nature antagonize your ethical sense, but you hesitate to commit yourself to this position lest you should repeat the folly of the adolescent who holds his elders in disdain. But you are not an adolescent. Look closely.

"There is perhaps nothing more characteristic of conceited youth than its cocksureness. The explanation of things is so clear to him that those of his elders who for some incomprehensible reason can not see for themselves had much better ask him about it. Why question and experiment? It is as plain as the nose on your face that it must be so and so. Common sense tells you that —if you have any!

"We reach our intellectual majority when we begin to realize that it is not quite so easy as all this; when we begin to question anew, as we did in childhood; when we become increasingly reluctant to commit ourselves to an opinion.

"Now the human race, as represented by its intellectuals, has passed through something strangely like this stage of adolescent conceit. There was nothing more characteristic of the thought of the Middle Ages than this same cocksureness, this disinclination to put questions to nature, this predilection for spinning explanations out of its own inner consciousness. Why look through Galileo's telescope to see what he calls 'the moons of Jupiter'? Are there not seven planets known? And is not seven a perfect number? There can be no more planets; it is a waste of time to look for them. And as for light bodies falling as fast as heavy ones, why, common sense would tell you differently, even if Aristotle had not done so. Who is this upstart that he pretends to know more than Aristotle? And of all presumption—to assert that he can see spots on the face of the perfect sun!

"But man is beginning to emerge from

this mental state, and is entering upon his intellectual manhood. You students of animate nature are in the forefront of the advance. You question, you observe, you experiment; you are hesitant about forming an opinion. You have reached years of discretion. Trust your vision, your reason. If something within you suggests that your ideals are superior to some things which you see in the established order of nature, if you, too, see spots on the sun, fear not, neither be ashamed. Ideals can rise higher than their source. Just as every great genius had parents of less than his own mental ability, who yet in some mysterious way endowed him with more than they themselves possessed, so nature has produced within us something without precedent in the life history of the earth. And as a parent watches with pride a child who gives early promise of outdistancing his elders, so Mother Nature may be watching us.

"It is all very interesting and amusing to sit, as it were, in a box at nature's theater and watch the Pageant of Time; to see life slowly and perilously begin; to watch it wax and develop to incredible complexity. But now the call comes to you; your cue is spoken. Within you is developing a new thing, as wonderful as life itself, and no less rich in possibilities. Life in its turn has brought forth something of a higher order, transcending itself, as it once transcended non-living nature. And that this new thing has elected to make its appearance in and through you, the highest of nature's children, what is more reasonable? Do men gather figs of thistles?

"What is this new thing which nature has brought forth, and with the development of which we have been entrusted? No man can say, but it is a fair inference that it will go far. Life has gone far from a tiny speck of protoplasm; who knows to what length this new thing, this mind, this soul, if you will, may carry us? But with all that we are, with all that we may become, we must ever bear in mind that nature is our mother, that in all that is fundamental we are one with that which we see about us; in substance the same, differing only in behavior."

ARTIFICIAL BEACH CONSTRUCTION IN THE VICINITY OF NEW YORK

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Although millions of dollars have been spent in the past few years to build beaches in various parts of the United States, the idea that beaches can be constructed artificially is strikingly novel to most people. Yet in recent years the growing popularity of the shore as a vacation resort has so emphasized the value of good beaches that an increasing number of municipalities, clubs and private individuals are seeking to better their bathing facilities by constructing artificial beaches. The success of these attempts has varied as widely as their cost.

As a rule the most successful beaches have been built by engineers thoroughly conversant with local physical conditions, who have provided structures to counteract the effects of these conditions or to shape them to their ends. Conditions vary so widely from place to place that rule-of-thumb methods are sure to give a large percentage of failures, and a structure successful at one place may be a dismal failure at another. On the other hand, the engineer who wishes to attack his problem scientifically finds that science has done very little to help him. He is almost entirely without trustworthy facts, and must work up his data from hasty studies of his own. Unfortunately the conditions of competition under which most beach contracts are awarded do not allow much expenditure of money for experimental purposes, so the builder is forced to work with imperfect information, with the result that many beaches never attain their greatest possible success.

At the suggestion of Professor Douglas Johnson, of the National Research Council's Committee on Shoreline Investigation, the writer made a study of certain artificial beaches in the vicinity of New York, in order to get a better idea of the magnitude of this type of engineering work and to discover, if possible, some of the physical conditions which help to determine the success or failure of man's attempts to build himself artificial seashore playgrounds. The results of such a survey are immensely impressive if one considers only the cost of such structures; while a double interest exists for those who have some curiosity as to how waves build up and tear away the sands along the shore. The city of New York has spent over $2,000,000 in building its public beach at Coney Island. Wrightsville, N. C., an incorporated town with a winter population of twenty-two persons, and a summer population of five thousand, has spent $60,000 in building jetties. At Atlantic City jetties constructed on an extensive scale have given satisfactory results. Thus, from large to small, the examples of beach construction finished or under way might be multiplied extensively.

In making his studies the writer was generously aided by more engineers and other competent authorities than he can name in a short article, and he wishes to express here his indebtedness to them and to their published accounts of special shore works.

Agents of Erosion and Accretion

An analysis of the work of erosion and accretion performed upon beaches will show that the chief agencies involved are waves and currents, usually interacting to such a degree that it is often difficult to arrive at an estimate of their relative importance. The destructive action of waves is dependent upon their size and character, the direction of their approach and the depth of the water. On a calm day waves approaching the beach are likely to be of the gentle swell type, and if the bottom slopes gently seaward, material should be moved landward to build up the beach. On the other hand, an onshore storm will pile the water upon the beach several feet above normal high tide, so that a strong hydraulic bottom current or undertow flowing seaward may be caused, disastrously eroding the beach. If the wind blows strongly offshore, the surface water will be blown seaward, and a compensating shoreward current coming in along the bottom will deposit sand upon the beach. That this is more than theory is indicated by the Jersey fisherman's axiom that "a west wind builds up the beach."

Another factor of extreme importance in determining the effect of waves on a beach is the depth of water seaward of it. Large waves require deep water; if a beach is protected by shallows offshore, the great waves will break harmlessly where the water first shoals. Only after a long storm will the ceaselessly working waves have removed material enough and deepened the water sufficiently to allow them to attack the shore. Usually the storm is over before this can happen, and the ordinary processes of deposition have replaced the sand before another storm. Thus it happens that one long-continued storm may do more damage than several short ones. When the water deepens rapidly offshore, even short storms are able to throw waves upon an unprotected beach which is open to destruction. It is true that the best protection a beach can have is "plenty of sand," so that it can lose much without being destroyed.

All the sand removed from a beach is seldom permanently lost; usually a large proportion is replaced during the next calm period, or after a change of winds. As an example, the fortunate case of the New Jersey coast may be cited, where the most destructive northeasters are usually followed for several days by steady west winds, rebuilding in many cases a large part of the destroyed beaches. But in places the difficulties of protection are increased by the permanent loss of a large part of the storm-eroded sand; this is true on the Netherlands coast, where the strong tidal currents of the North Sea remove the sand beyond the hope of reclamation.

This interaction of waves and currents working toward the construction or destruction of a beach is typical of the forces with which the marine engineer must struggle. Authorities differ greatly concerning the work of tides on beaches, but it seems most probable that the ordinary rise and fall of tides will have little effect on an open coast. Tidal currents having a velocity of several miles per hour may develop on certain parts of a coast broken by many inlets, bays and headlands.

On the Jersey coast inlets through the barrier beach are marked by two tidal deltas, one in the lagoon and one in the ocean, formed by the inflowing and outflowing tidal currents. The sand in these deltas is permanently removed from beach circulation, and therefore such tidal currents may have a detrimental influence by robbing the beaches.

Wave currents, last to be considered, are the producers of "beach drifting," probably the most important means of transportation by which beaches are built up or destroyed. Beach drifting is caused by waves running upon the beach obliquely and forming a swash which carries beach material in the direction of wave propagation up the beach, whence the force of gravity causes it to return almost directly down the slope. Thus wave after wave results in a net movement of material to leeward by a series of parabolic leaps. The importance of this process is everywhere demonstrated by the accumulation of sand found on the windward side of any obstacle which obstructs the movement of drift along the beach. Many prominent features of our coasts owe their existence to this drifting movement: Sandy Hook and Rockaway Point, outside the Lower Bay of New York, are due to drifting caused by wave currents, and both have been rapidly extended in the direction of current movement.

SHORE PROTECTIVE DEVICES

Engineering opinion differs greatly concerning the value of artificial defenses used to protect beaches against loss. A limited number have proven useful under such a variety of conditions that no doubt remains about their utility, although there is still much argument about their detailed construction. It may be said that any structure sufficiently tight to interrupt the beach drifting will result in accumulation on the side from which the drift comes, but such effects may be offset by the scour which may be caused at times on their leeward side.

Protective devices are generally of the following types: bulkheads, placed at the rear of the beach and extending parallel to the shore, are made of wood, stone or concrete, and are designed to prevent erosion and scour on beaches inundated by extreme storms. Groins, by which are understood wooden or stone structures usually placed at right angles to the shore and extending into the ocean far enough to break up the long-shore movement of drift, are the most important beach protective device. Many disastrous experiences have shown that groins or bulkheads should seldom if ever be used separately; a system of groins having their landward ends tied to a bulkhead is considered the best engineering practice. Groins designed to secure accretion to the beach are usually built with piles projecting so they may be raised as deposition occurs. When they are exposed to the full effect of the waves they must be protected by massive riprap, or be made entirely of stone; wooden groins will be torn out, as happened at Long Beach during the recent storm of February 22. Groins are usually placed at right angles to the shore, and are spaced variously according to local conditions.

PHYSICAL CONDITIONS IN THE VICINITY OF NEW YORK

The effect of the wind, the usual cause of shore drifting, may be studied by wind "roses," made by plotting the relative importance of the wind from each quarter obtained by multiplying the hours of duration from each direction by the average hourly velocity. The use of wind "roses" in explaining the direction of beach drifting as a function of dominant winds and coastal orientation is well exemplified by the cases of the southern Long Island and New Jersey coasts.

The northern coast of New Jersey extends in a north-south direction, and drifting is northward, while the adjacent Long Island coast has an east-west orientation, with westward drifting. For a long time these anomalous directions of drift movement confused students of shoreline problems, but the explanation is now known to be very simple and logical. Obviously the only winds capable of producing oblique onshore waves on the Long Island coast are from the southeast and southwest. The wind "rose" for Sandy Hook shows the southeast winds to be less important, and eastward beach drifting due to the stronger southwest winds should be expected. However, winds coming from the southwest have a shorter sweep of open water due to the nearness of the Jersey coast, while the southeast winds sweep in from the open ocean and are therefore strong enough to bring about westward drifting.

On the north-south New Jersey coast, waves from the northeast and southeast approach the shore obliquely to cause drifting, but although the northeasters are the stronger winds, the coast is partially protected by the proximity of Long Island, and the weaker southeast winds are able to form the stronger waves with very marked northward movement of material along the northern New Jersey coast. A rough diagram will convince any one of the validity of this explanation for the movement of material on these coasts.

The straight linear character of the New Jersey and southern Long Island coasts is ideal for the generation of shore currents moving for great distances in the same direction; on the other hand, the Connecticut shore of Long Island Sound is so irregular that the many minor indentations and prominences exercise a great influence over the direction of beach drifting, and currents setting for a long distance in the same direction are unusual. The difficulties of beach construction on the Connecticut shore are increased because the natural supply of sand is smaller than on the Long Island and New Jersey coasts, where unconsolidated sands and gravels supply to the waves an abundance of material for the beaches, whereas, in Connecticut, a large proportion of the shore is formed of resistant crystalline rock disintegrating to form sand very slowly.

The Coney Island Municipal Beach

The largest and most successful artificial beach on the North Atlantic coast is the New York City Municipal Beach at Coney Island on the southwest point of Long Island just outside New York Harbor. Here, on a front of nearly two miles, the shoreline has been advanced seaward over three hundred feet by artificial means. Before construction started there was a natural beach some fifty feet wide, protected by a few privately built groins, but no systematic protection was afforded so that advance in one place was offset by retreat in another. The natural supply of sand was insufficient to build a beach of the desired width, so that it was necessary to pump sand upon the beach. The chief problem of the engineers was to determine what type of structure would give the greatest stability to the sand thus placed.

Careful study resulted in the erection of sixteen timber groins, each five hundred and sixty feet long, and spaced at six-hundred-foot intervals. All these groins were securely tied to a low bulkhead to prevent scouring in case of exceptionally severe storms and were covered by heavy riprap for their outer two hundred feet.

At present, several years after the completion of the work, many interesting features are revealed. Since the general movement of material on this coast is westward, it is to be expected that all the groins interrupting the drifting would have more sand on their eastern side than on the western. At Coney Island this is true of the eleven western groins, showing that movement on the western portion of the beach is westward. In addition, a large quantity of red sand was poured upon the beach during construction at a point about one thousand feet west of Steeplechase Pier; a few months later this sand was found several thousand feet west of, and more than a thousand feet eastward of its original position. Finally, improved beaches to the east, stable for many years, have suddenly moved forward over a hundred feet since the completion of the Coney Island beach. All this evidence points to an unusual change in the direction of beach drifting, so that east of a certain point on the beach, probably in the vicinity of the twelfth groin, sand moves eastward instead of westward.

A number of explanations have been advanced to account for this interesting change in the direction of beach drifting, the most promising being based upon a study of the location of Coney Island in reference to the protection afforded against sea winds. As any map will show, the eastern shore of Coney Island is protected by Rockaway Point from the heavy southeast waves which sweep in with full force upon the western portion of the Island. On the other hand, waves coming to Coney from the southwest have only a short fetch, due to the nearness of the New Jersey shore; they are wholly incapable of moving material eastward on the western portion of the beach where the heavy southeast waves break. On the eastern portion of the beach, however, they have a greater fetch than the southeast waves crossing the narrow stretch of open water behind Rockaway Point. Here, therefore, the southwesters are dominant, and cause an eastward movement of shore débris. The vicinity of the twelfth groin from the west is where the domination of southwest waves on the eastern portion of the beach gives way to the domination of southeast waves on the western portion, and hence is the point from which material is moved in both directions. The authorities take advantage of this unusual movement of shore drift to replenish the beach at intervals; they simply pump sand on the shore in the vicinity of groin 12, and the waves distribute it all along the shorefront. This has allowed economical maintenance of the beach, which is considered very successful several years after its completion.

BEACHES ON THE WESTCHESTER COUNTY SHORE

Although conditions of beach construction on the north shore of Long Island Sound are very different from those on the south shore of Long Island, it is still true that the solution of the problem will be found by a proper appreciation of the movement of beach material as governed by the direction of approach of the dominant waves. In making plans for the construction of a beach it will always be found helpful to study other beaches in the vicinity in order to learn what conditions have governed their development. In the course of field work in Westchester County, three adjoining natural beaches, Meadow, Rye and Oakland, were visited, and showed a distribution of sand highly significant of their origin.

Meadow Beach, the northmost of the three, is situated between two small rocky promontories; the northeastern portion of this beach has a broad strip of sand which narrows rapidly toward the southwest until it is only a few feet wide. The cause of this uneven distribution is not far to seek. A short distance offshore are the Transport Rocks, largely protecting the beach from the onslaughts of southeast waves, but to the south and the east the beach is exposed. In this region south winds are stronger than easterlies, so that the dominant waves are from the south. Meeting the northeastward extending shore obliquely, they cause drifting toward the northeast, until the northern promontory breaks up the movement causing the formation of a wider strip of beach.

Adjacent to Meadow Beach on the southwest is Rye Beach, a broad, fine beach, sheltered, as is the former, by two rock promontories. Here again the distribution of sand is uneven, but unlike Meadow Beach the southern portion is broader than the northern. The presence of offshore rocks explains the apparent anomaly. To the south and southeast lie the Forlies Rocks; to the east lie the Transport Rocks, but to the northeast the beach is exposed to waves coming in over a long stretch of open water causing southwesterly drifting until the interference of the southern rock causes deposition on that portion of the beach.

Oakland Beach is situated a short distance south of Rye Beach, and if the position of the rocks offshore is noted it will be seen that the beach is well protected from north through east by the nearby Forlies Rocks, but to the southeast it is more exposed. Southeast waves should here cause beach drifting in a northerly direction, and the beach should be wide at the northern end, if the theory is correct. In the field one glance shows that the facts conform to theory, and that the northern portion is wider.

Here, then, is a series of three beaches, two of which are wider at their northern ends, while the third, lying between the former, is much broader at the southern end. This irregular distribution of sand is a strong argument against the presence of currents setting for a long distance in one direction such as are found along the Long Island and most of the New Jersey coast. As has been shown, the distribution of sand in each case is explained by the direction from which comes the dominant wind blowing across the greatest stretch of open water. With this in view, it seems evident that on this coast marine engineers should give particular attention to the often slighted, but here very important, process of beach drifting.

Investigations of this character show very clearly how the study of shorelines and shore forms so long classed as one of the "pure" geological sciences has in the last few years taken its place with so many of its sister branches of geology as a subject of distinct practical value. It also indicates how much the lives and habits of the present generation have been influenced by the invention of the automobile; before it became cheap and plentiful the beaches were more than large enough to accommodate all who visited them. Now they are overwhelmed with visitors, and efficient means of enlarging and increasing them are eagerly being sought.

THE SOIL AND THE MICROBE[1]

By Dr. SELMAN A. WAKSMAN

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THE practical benefits derived from the study of the rôle of microorganisms in infectious diseases and of the means of controlling these infections, as a result of the investigations of Pasteur, Koch, their associates and numerous followers, gave rise to expectations of similar results in other fields, where the transformations are known to depend largely upon the agency of microbes. However, these expectations were not always fulfilled, and frequently the results obtained gave little promise of practical exploitation. This is especially true in the application of the results of studies of numerous microorganisms which inhabit the soil. If the primary purpose of scientific investigation is to explain known facts and common practices, then the study of the biochemical processes carried on in the soil by the complex population may have justified itself. However, if the primary purpose of research is to improve or change common practice, then the fifty years of study of the bacteria and other microbes of the soil has with certain exceptions, such as the use of cultures for soil inoculation and a better understanding of the employment of green manures and the use of stable manure, largely failed in its goal.

Far from agreeing in the interpretation of the results obtained, outstanding investigators in the field frequently dispute the very activities ascribed to the great majority of soil organisms and even question whether any of the organisms commonly studied have been definitely shown to be soil forms and the causative agents of known processes. Soil microbiology represents a good illustration of a science which is quite dependent upon information in related sciences.

Since the importance of microorganisms in soils is interpreted in terms of the influence of these organisms upon growth of higher plants and since the complex physical and chemical properties of soils are so closely related to plant development, a knowledge of the factors affecting plant growth and of the physical and chemical characteristics of soils is indispensable to applications of findings in soil microbiology. To be able to understand the reason for the crop-producing capacity of the soil, the processes of soil treatment and fertilization, it is not merely sufficient to know the nutrient requirements of the plant, but it is essential to understand the factors affecting the liberation and retention of these nutrients in the soil, processes which are closely related to the activities of the soil microbes. These microbes have become too quickly popular as a result of a few partly justified and many largely unjustified expectations. Many are found who are willing to exploit for selfish purposes this interest of the practical man in the microbe, an interest so well blended with a lack of accurate knowledge. A soil process whose explanation is obscure may be called a result of the action of soil bacteria with little or no knowledge of the importance of such organisms in the reaction. Even the teacher and agricultural expert utilize this explanation, when one is needed and none is available; the microbes in the soil has served too frequently for explaining phenomena which were not understood.

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What do we know of these soil microbes? Can we ever expect that an extension of our knowledge will lead to a modification of soil treatment and help to change this art of handling soils into a science which will take its place with other biological sciences. It may be somewhat exaggerated to call soil science a biological science, especially in view of the secondary considerations given to soil organisms, as compared with the mechanical, physical and chemical analysis of the soil, but it will be recognized sooner or later that the soil is a biological system, modified by the physical and chemical environments just as other biological systems are.

The foundations for the knowledge of the microbes of the soil were laid by (1) chemists, who have studied certain soil processes, such as the formation of nitrates or the fixation of atmospheric nitrogen; (2) by bacteriologists, botanists and zoologists, who developed methods for the isolation and cultivation of bacteria and other microorganisms, and finally (3) by practical agronomists, who studied plants in their natural environment, the soil. It is sufficient to mention the names of such brilliant chemists as Berthelot and Müntz, in France, of Lawes and Gilbert, in England, of Sprengel and Liebig, in Germany; bacteriologists, like L. Pasteur, F. Cohn, R. Koch; agronomists, like Kette, Rosenberg-Lipinsky, Dehérain and others. Although by 1880 considerable information had accumulated concerning certain soil processes and their importance in plant nutrition, very little was known of the causative agents. The soil was supposed to harbor microscopic forms, but these were very little understood.

The development of the gelatin plate method in 1881 by R. Koch enabled one to obtain bacteria from the soil. The application of this method by Koch and other bacteriologists demonstrated the presence of millions of these organisms in every gram of soil. This striking observation aroused general expectations that soil practice would soon be revolutionized, just as was the case with the practice of medicine. Unfortunately, however, one could find at the very beginning of these investigations the seeds of future disappointments. First, the investigators, especially in Germany, were either medical men who were little interested in the soil as a biological system, but were searching for organisms that might be causative agents of animal diseases and not for the organisms which were concerned in the important soil processes; or they were practical men, interested in the modification of the soil economy rather than in the development of a new science. Secondly, since only bacteria were at that time recognized to be concerned with animal diseases, bacteria were sought in the soil and bacteria were counted, thus giving rise to the name of the whole science under consideration as "soil bacteriology," overlooking thereby the fact that the soil harbors numerous other organisms which take an active part in the various processes. Finally, the plate method of counting bacteria, being fairly well adapted to counting known specific bacteria, gave a wrong impression of the occurrence and abundance of the bacteria in the soil, since it allowed the development of very few types of organisms. The great majority of the soil bacteria and especially those known to carry out certain important soil processes, being very selective in their nutrition, did not develop on the plate, so that where hundreds of millions occur per gram of soil only millions or even fewer were counted.

Soon after the work of Koch there appeared one of the most important contributions from the applied point of view. In 1885–1886 the studies of the rôle of bacteria in the fixation of nitrogen by leguminous plants were brought to a final successful conclusion. From the times of the Romans it was known that these plants could thrive very well on soils where other plants failed. It was later shown that they could develop on soils receiving no additional combined nitrogen, either in organic or inorganic forms; they were known to leave the soil not poorer but even richer in this valuable element, which is indispensable for the growth of all plants and which is the most costly of all the fertilizing elements supplied to the soil. These plants were found to contain nodules on their roots, the nodules being full of bacteria. Hellriegel and Wilfarth, in Germany, followed by other investigators, established beyond any doubt that the leguminous plants are capable of obtaining the nitrogen from the abundant supply of gaseous atmospheric nitrogen and that the presence of the bacteria in the nodules is absolutely essential to this process. When the bacteria are eliminated, the leguminous plants behave like all other plants and require additional nitrogen. When the soil in which the plants are grown is inoculated with the bacteria in question, the plants begin to grow very rapidly, as when available nitrogen is added. Whether the bacteria themselves fix the nitrogen or whether they enable the plant to do that by some unknown process, was a question of some discussion, although the evidence seems to point quite definitely to the first theory.

The period between 1890 and 1902–1904 abounded in some outstanding contributions to our knowledge of soil microorganisms. Two investigators, who have already made some important contributions to microbiology, namely, S. Winogradsky and W. M. Beijerinck, focussed their attention upon organisms related to some specific soil processes and succeeded in unravelling a number of processes until then only little understood. These investigators developed new methods of attack, which enabled them to isolate organisms that could not be isolated by the ordinary bacteriological methods. These forms were shown to be concerned with certain known processes and were studied in attempts to explain the nature of the processes themselves. The enrichment culture method and the use of synthetic media, some of which were highly specific, allowed the isolation of various new microbes. It is sufficient to mention the organisms responsible for the formation of nitrites and nitrates (it is this latter form of nitrogen which is largely used by the higher plants), the fixation of atmospheric nitrogen in the absence of leguminous plants, under aerobic and anaerobic conditions, the oxidation of sulfur and its compounds and the reduction of nitrates to atmospheric nitrogen.

During this period other investigators made numerous contributions some of which are of outstanding importance. Attention need only be called to the investigations on the rôle of microorganisms in the decomposition of proteins with the liberation of ammonia. This is a reverse process of that carried out by higher plants, and it results in retaining the important element nitrogen in constant circulation in its combined form, of which there is only a limited supply in the soil. Other studies were concerned also with the decomposition of celluloses and other organic complexes, with the liberation of the carbon in the form of carbon dioxide, which becomes available to the growing plant.

All these studies increased the information on the nature of the organisms concerned in some definite soil processes; as a matter of fact, only organisms were looked for which were responsible for processes already known. However, the investigations tended to be isolated phenomena and, although they contributed to the accumulation of knowledge concerning certain representatives of the soil population, they did not tend to bring to light the various interrelationships of the complex soil population. These microbes live in an extremely complex physical and chemical medium, the soil. They exist in the soil solution and to a greater extent on the organic and inorganic colloidal film surrounding the inorganic particles which go to make up the soil. They carry out numerous reactions, utilizing the products of one another, antagonizing one another directly or indirectly, working frequently in symbiosis, producing substances injurious to themselves or to others and frequently serving as food to other organisms. A single process carried out by a single organism gives only a suggestion of the course of the same process in the soil or of the rôle of the particular microbe in this process when accompanied by numerous other processes, in the presence of a very complex population of fungi, bacteria, actinomyces, algae, protozoa, nematodes, etc.

Such considerations and a desire to study certain transformations in the soil in the presence of the mixed population, rather than by specific forms in pure culture, called forth about 1902 two new methods of study of soil biological processes:

(1) Some investigators limited themselves to the determination of a single transformation or group of transformations brought about by the whole soil population. The soil was at first added to a solution containing a definite substance, later the substance in question was added to the soil itself. After a certain brief period of incubation, an analysis was made of one intermediary or final product, which could serve as an index of the transformation brought about by the microorganisms. If the substance used was a protein, a protein derivative or a complex organic substance rich in proteins, ammonia was usually determined, with the assumption that the more active the microbes are in the particular soil the more ammonia is produced in a given period of time, as a result of the decomposition of the protein. If the substance in question was an ammonium salt, nitrate was measured as the transformation product, with similar considerations. If the fixation of atmospheric nitrogen was studied, an excess of an available source of energy, like mannitol or glucose, was used. Certain correlations were actually obtained between the fertility of the soil and the rapidity of transformations thus brought about, either in solution or in soil, resulting from the activities of the soil microflora and microfauna. It was thus argued that the more active a soil is biologically the more fertile it is; nothing definite was known as to whether one was a result of the other or whether both were influenced alike by the same soil conditions.

(2) The dilution method, suggested by Hiltner and Störmer, in Germany, and Chester in this country, consisted of counting the abundance of certain physiological groups of bacteria, capable of bringing about certain definite transformations.

The second method was utilized only to a very limited extent. It was the first method that found extensive application, due largely to the simplicity of the procedure and to the fact that a knowledge of the complex soil population was not required. The study of the complex soil population and its activities was thus reduced to a few simple manipulations, which could be carried out readily without any expensive equipment and without any extensive information concerning the numerous microorganisms inhabiting the soil and the complex biochemical processes carried out by these organisms. Soon every agricultural institution in every civilized country was devoting full or part time of one or more experimenters to a study of soil processes, using the above-mentioned manipulations, repeated manyfold under various conditions and in various manners. The general impression prevailed that whatever was to be known of soil microorganisms and their rôle in soil processes was already known and that it merely remained to utilize the methods thus developed, just as so many methods in analytical chemistry.

A considerable literature dealing with results obtained by these methods has accumulated. Some of this information helped to advance our knowledge concerning certain soil processes, largely the transformation of nitrogen in the soil, the use of stable manures and green manures, the use of lime and other questions related more to practical soil management than to the solution of the fundamental problems of soil science. The above methods of investigation of soil processes could not advance appreciably our knowledge of the fundamental soil processes, due to the fact that neither the organisms concerned nor the numerous intermediary processes were considered sufficiently and the evidence accumulated could only be circumstantial and of local application. This was largely the reason that, within a decade and a half, there was a practically complete cessation of studies based on solution or soil methods and a considerable reduction both in the number of experimenters and in the literature on soil transformations.

The same period (last two decades) witnessed a growing interest in the other members of the soil population, especially the fungi, actinomyces and algae, belonging to the plant kingdom, and the protozoa and nematodes among the animals.

One of the most interesting ideas, which served as a decided stimulus to the study of the complexities of the soil population, was the protozoan theory of soil fertility proposed by Russell and his associates in England. These investigators limited themselves to the existence in the soil of only two groups of organisms, namely, the protozoa and the bacteria. In their investigations only one biological process was studied, namely, ammonia accumulation in soil. Treatment of soil with volatile antiseptics and dry or moist heat, known as partial sterilization, was known to result in an increase in the fertility of the soil. This increase in soil fertility is accompanied, on the one hand, by an initial reduction followed by a very rapid increase in the numbers of bacteria and an accumulation of ammonia nitrogen, and, on the other hand, by a partial if not complete destruction of the protozoa. Since protozoa are known to feed upon bacteria, the idea was suggested that, in normal soils, bacterial development is kept in check by the protozoa. When these animals are destroyed by partial sterilization, the bacteria develop unhindered and bring about an extensive decomposition of the soil organic matter, thus liberating the valuable element nitrogen as ammonia, which leads to a more extensive crop growth.

Russell and associates thus succeeded in developing a unique theory of soil fertility on the basis of the interrelationships of the protozoa and the bacteria.

This theory led to extensive studies of the animal population of the soil and its relation to other groups of soil microorganisms. The information obtained as a result of these studies can be summarized under three headings: (1) In addition to the protozoa, various other groups of soil organisms, especially the fungi, were also found to be eliminated by partial sterilization of soil. An active competition was found to exist between the fungi and the bacteria for the available energy in the soil, as represented by the soil organic matter. (2) Treatment of soil with antiseptics actually does not destroy all the protozoa. (3) When protozoa are added to bacterial cultures, under controlled conditions, the processes brought about by the bacteria are found not to be injured, but are in many instances even stimulated.

The microbes of the soil form so complex a population and take part in so many activities that it is futile to attempt to explain the various intricate soil processes by a simple theory based upon the interaction of two constituent groups of the soil population; it is further unlikely that one simple transformation product can explain the complex series of processes resulting from the interaction of the mixed soil population.

One acre of soil contains two million pounds, on the basis of only the upper six and one half inches of the soil. A pound contains four hundred and fifty grams. One gram of an average field soil contains:

One hundred million to three billion bacteria, out of which only one to fifty millions actually develop on the plate.

Ten thousand to one million fungi, representing both fungus spores and pieces of mycelium, the latter being especially abundant in forest and in acid soils.

Ten thousand to twenty million actinomyces also represented in the soil by spores and mycelium.

Ten thousand to one million protozoa represented in the soil by the flagellates, amoebae and ciliates.

Many thousands of cells of algae, including blue-greens, grass-greens and diatoms.

Numerous nematodes, rotifers, insect larvae, etc.

Among the transformations carried out by the bacteria, fungi, algae and actinomyces, it is sufficient to mention:

Decomposition of celluloses, pentosans, proteins and other constituents of the natural organic matter added to the soil in the form of plant and animal residues.

Assimilation processes, resulting in the building up of complex organic compounds by the numerous microorganisms, using the nitrogen compounds and minerals liberated in the decomposition of plant and animal residues.

Oxidation processes, resulting in the formation of nitrites, nitrates, sulfates and various oxidized organic compounds.

Reduction processes, resulting in the reduction of nitrates to nitrites, ammonia, oxides of nitrogen and atmospheric nitrogen; of sulfates to sulfides and the reduction of various organic compounds.

Fixation of atmospheric nitrogen.

Formation of various organic and inorganic acids, which interact with the mineral complexes in the soil, leading to a change in reaction, increase in solubility of insoluble compounds, etc.

The presence of protozoa and other members of the animal population still further complicates the above processes, since these organisms feed on the living and dead bacteria, fungi and algae, as well as on the undecomposed and partially decomposed organic matter, and, later in their turn, also undergo decomposition.

This soil population is so complex, the activities are so numerous, our knowledge is so limited, our methods are still so crude, that we are still unable to construct an intelligent system of soil processes. The opportunities in this field for gaining knowledge, and adding valuable information, which is bound to be of tremendous scientific and practical interest, are great. The soil and the microbe await the investigator, first of all the chemist, the physicist, the biologist, who are not looking for practical gains but for explaining the obscure and observing the unknown. The application will doubtless come.

WHAT IS A POLITICAL ANIMAL?

By Professor EZRA BOWEN
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MAN is by nature a political animal, hence the state. Aristotle, who collected the first zoo, worked up this interesting bit of dogma twenty-five hundred years ago, and down through the centuries from sage to sage it is whispered as the pass-word of political scientists. The standard coin to which the small change of political thought is referred for valuation, it still retains full currency. In text-books, those universal thought-fossilizing mediums, it is usually preserved in original form.

Man is by nature a religious animal, hence the church. Man is by nature a vicious animal, hence vice. Man is by nature ruminative, hence chicle. All as plain as spirit writing—and no more satisfying.

Disraeli, walking in the garden with Dean Stanley, interrupted the good dean's rant against dogma: "Remember, dear dean, No dogma, no dean." Then who can blame the high priests of political science for turning a stony face upon reason and spurning the simple idea that the state is a common law corporation—too simple an idea perhaps for serious pedagogic purpose? Their apology, however, is not far to find—that much they have written out: Simply, in all history there is no record of such a corporation's being formed!

Now a flounder or a sole has both eyes on one side of his head; and biologists have a convenient agreement that it was not always so: that the flounder, travelling continually on one side, with one eye in the sand, found it more convenient to have both eyes on the upper side of him. Yet the biologists, quite as sober-minded and honest as political scientists, have no documentary evidence of a meeting of soles off the coast of Normandy—or of Provincetown flounders—to declare against the one eye to a side idea and for all eyes up all the time. Why, then, should the political scientist require a photostat of minutes showing a resolution, properly moved and seconded, creating a superior will from surrendered fragments of individual free will—this superior will to prevail in any conflict with the individual?

"Am I to believe that the beautiful human eye with the light of the soul shining through was descended from a freckle?" Now we are quoting Mr. Bryan, W. J. Of course we did not expect Mr. Bryan to come to so close a grip with the divine, nor did we expect him to believe that the resultant force of an infinity of circumstances, working over an indefinitely great number of years, produced the lantern of the firefly. "*Whereas*, we the United and Fraternal Order of Night Flies have experienced great inconvenience and some danger, . . . etc., etc. Be it *resolved* that each and every member of the Order be required to carry a small, intermittent, cold light in the posterior portion of his person, etc., etc." No, Mr. Bryan, we can not produce that evidence. Nor can we put before the orthodoxy of political science a bundle of musty papers detailing the agreement whereby any one of the thousands of common law corporations called a state come into existence. We know only that states, huge masses of fabricated will-power, expressing themselves through an organization of one form or another, exist and have existed as far back as history's dull nose holds the scent.

A science is an estimate: All substance is composed of earth, air, fire or water. That is not true; but it was true—as far as any science is ever true. It was the most reasonable explanation of things at the time of its currency. All matter is composed of indivisible, infinitesimal, ultimate particles called atoms. This is not true, but it was true—as far as any science is ever true. We of the present generation, sacrificed on that altar, burned our candles and mumbled the ritual. Again, Newton's law of gravitation is not true: It is practicably true, but not perfectly true. (At least, that is what Einstein tells us.) All knowledge, all scientific law is merely the current estimate of things and their workings—a temporary working agreement among the experts. Political science needs a new estimate, a new working agreement as to the nature of the state. Man is a political animal, hence the state—that estimate of the state is as old-fashioned as an earth-air-fire-and-water theory of matter.

Imagine a populated area where no political arrangements exist; then compare this with a known example of a primitive tribal state; the net difference is the concept or idea, the state. Is it not clear that this difference could come into our original situation only through the formation (implicit if not explicit) of a common law corporation, an artificial, imaginary entity imbued with power expressed through organization? This organization is government. The donated, isolated mass of power is the state. It is human power. No additional human power could come from without. It must then have been fabricated from fragments of free will surrendered by all included individuals. Each individual (we are speaking figuratively now, Mr. Bryan) whittles off a portion of his free will, his right to act out his mind. He pools this with similar bits of free will surrendered by all whom inclination or circumstance force into his group. The new, artificial, pooled will, an externally irresponsible, planetesimal mass of will-power, is the state.

It is probably true that the protozoan state was the family, that it was sinewed by the necessities of regeneration and subsistence, that organization or government came in only as a tertiary consideration to further these fundamental ends; but these facts do not forbid our considering, in a purely political study, that we are dealing with a purely political growth. The advantages of organization, vitalized by delegated power, would have sufficed to bring forth such units without the biologic-economic bond. That tertiary political sinews grew within an already living body ought not to obscure the fact that they could have formed a body of their own. On this warrant do we postulate the fabrication of an imaginary person, a common law corporation, *the state,* exercising certain specific, delegated functions through its agent or system of agents, *the government,* according to formulated rule and accumulating custom, *the law.*

Let us be more specific: Here is a primordial settlement in a luxuriant natural basin. From hill top to hill top, the basin is twenty miles across; it supports a population of a hundred persons. Every one is free, totally and dismally free. Free as the fox under the hill, free as the wolf, the grasshopper or the butterfly. There is no law, no government, no state. There are a number of semi-observed courtesies and conventions not unlike our present international "law." But when passions rise and reason falls a prey to ambition these courtesies and conventions are forgotten.

One canny and far-seeing soul gathers a hoard of succulent roots, stores them in a cave for the winter. Two covetous beasts of fellows plot, kill him and take the roots. Every one hears of it. It is deplored. The killing of a man is declared bad form. How can any one collect roots or otherwise provide for life, if it is but to court a violent end? Again and again this killing nuisance breaks out. Free expression of every impulse is manifestly bad. The exercise of free will in the taking of life or property must be surrendered by all individuals. It must be pooled: trusteed. A conclave is held. The right to kill and the right to take are placed in trust. Many object to this rank interference with personal liberty. But they are taken outside and their heads are cracked—a fitting initial exercise, by the trustees, of the newly created, pooled mass of power.

The trustees may be the whole people. That would be a democracy, a town-meeting government. Or a group of representatives may exercise the power—a republican form of government. Or there may be but one trustee (L'etat, c'est moi), a great, burly, hoary fellow, strangely but pleasantly honest, even and reserved. Probably the single chieftain ruling alone was the earliest form of government, and all primordial states were family or clan matters.

We admit there is no scrap of historical evidence of such a meeting of minds, and we let the truth of our theory rest solely upon the fact that it explains—offers the best *working explanation* of the state. The most elderly and respected of theories in whatever science has no higher claim to place.

Can zoologists prove an agreement among sea lions that flippers front and nothing rear were better than four legs—or furnish documented description of the drawing in of pedal extremities and the webbing over of digits? And perhaps their explanation does not follow the pattern of perfect truth. All turning-points in science shout denial. Perfect truth is as indefinite as the ether, but quite definitely, the history of science is a graveyard of things less perfect. But here is the present working agreement among specialists in zoology. Within their experience, it works, it explains. From the long range point of view it is only workably true; but for the moment that is now passing since nothing better offers, it is, in merely scientific sense, absolutely true. The earth-air-fire-and-water theory of matter, the atomic theory of matter, the proton-electron theory of matter, all true in their day—true as long as they offer the best available *working explanation* of things—are superseded when something new wins the confidence of sane minds.

Man is a political animal, hence the state—this theory of the state was true from Aristotle to Gettell. Lazy, presumptuous and very thin, still it formed a working agreement. But a common-law-corporation theory of the state throws far more light upon the essential nature and workings of the state. It is a *working explanation*. For to-day, true—true because it polarizes, arranges about itself, the facts of political life more neatly than any current explanation.

OYSTER FARMING[1]

By HERBERT F. PRYTHERCH

U. S. BUREAU OF FISHERIES

As you partake of a piping hot oyster stew or six cool delicious bluepoints on the half shell, it may interest you to know how this shellfish has been produced.

The oyster industry of the United States constitutes its most valuable fishery, yielding annually about 73,000 tons of food, employing over 65,000 persons, and producing each year a crop valued at over $14,000,000 as it is taken from the water. The oyster fishery is conducted in every seacoast state from Cape Cod to the Rio Grande and from Puget Sound to San Francisco.

Oysters do not grow in the open sea, but in harbors, bays, river mouths, or in other partially enclosed bodies of water which are made brackish by the drainage of fresh water from the land. In such places, as for instance, Long Island Sound and Chesapeake Bay, the mixture of fresh and salt water furnishes the conditions which are necessary and favorable for oyster growth and propagation. The oysters that are produced in the United States come from two main sources, namely, the natural beds and the cultivated beds.

The natural oyster beds, covering millions of acres of bottom in our coastal waters, represent a great national resource, but like most of our natural resources they have become sadly depleted. When the first settlers came to the shores of America, one of the most impressive indications of the richness of the new land was the great abundance, the large size and the excellence of the oysters which they found. The Indians along the coast subsisted largely on oysters, leaving great mounds of shells as mute evidence of the fact that they celebrated their feasts with this delicious bivalve. With the advance of civilization and increased population, the demand for oysters became greater and resulted in intensive operation of this fishery. In a very short time the supposedly inexhaustible natural beds were considerably depleted, so it was obvious that, lest the supply should fail, man must lend a hand much as he had in the raising of land crops.

The oyster lends itself readily to cultivation, first, because it is unable to move of its own volition from the beds on which it is placed; second, because it can withstand rough handling and long exposure to air; and third, because of its interesting and unusual life history, which makes possible unique methods for controlling and increasing its production.

Oysters spawn during the summer months, a single female oyster producing from ten to sixty million eggs, which are forcibly discharged into the water and after fertilization by the elements from the male oyster develop into what are known as oyster larvae. These larvae, which are microscopic in size, swim about in the water or lie on the bottom for a period of about two weeks, after which they cement themselves to some clean hard surface such as that of shells or rocks. These tiny oysters when attached or "set" on an old shell appear as small dark specks, and some idea as to their size can be gained from the fact that over a thousand have been found on a single square inch of shell,

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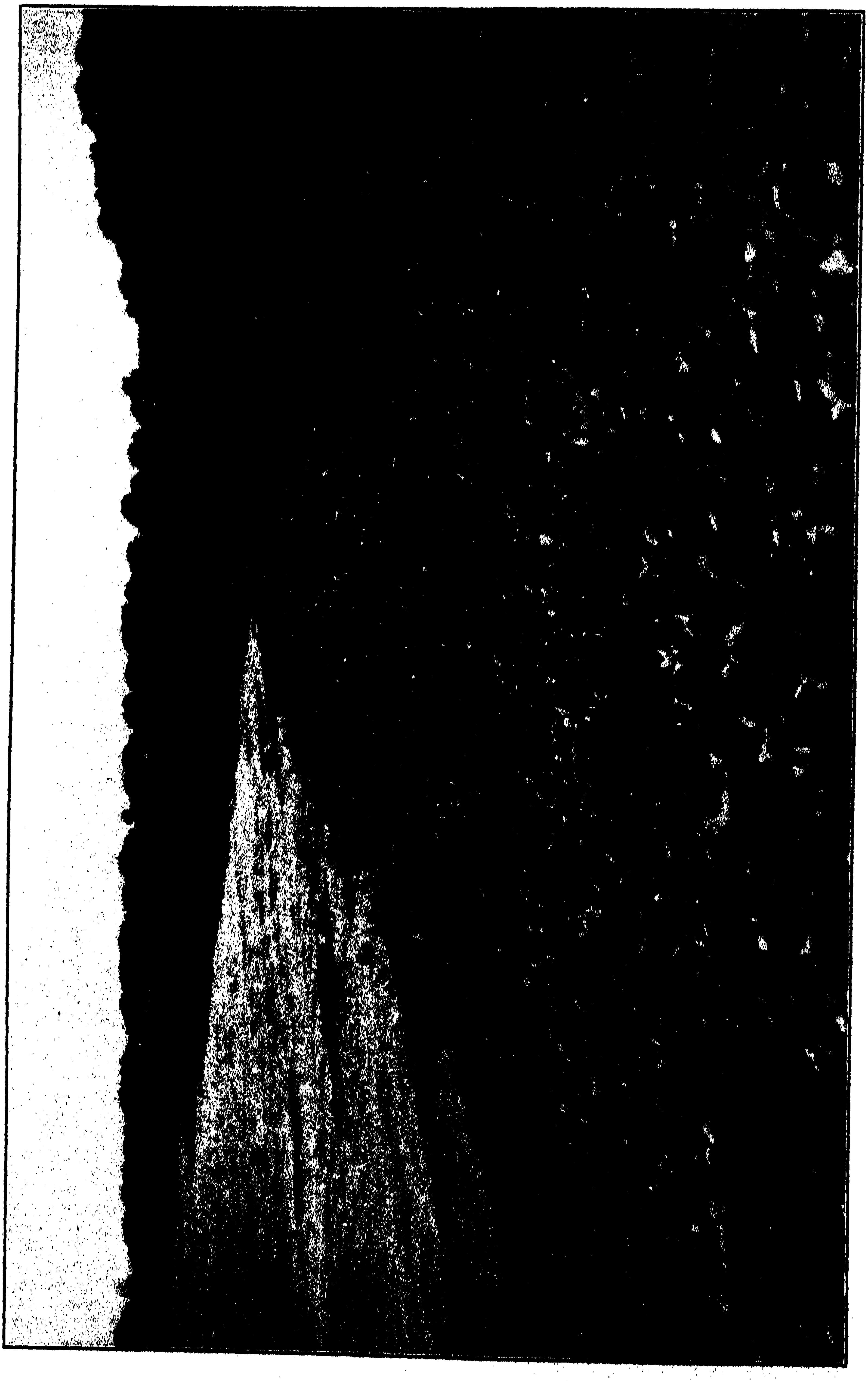
[1] One of the Smithsonian series of radio talks arranged by Mr. Austin H. Clark and given from Station WRC, Washington.

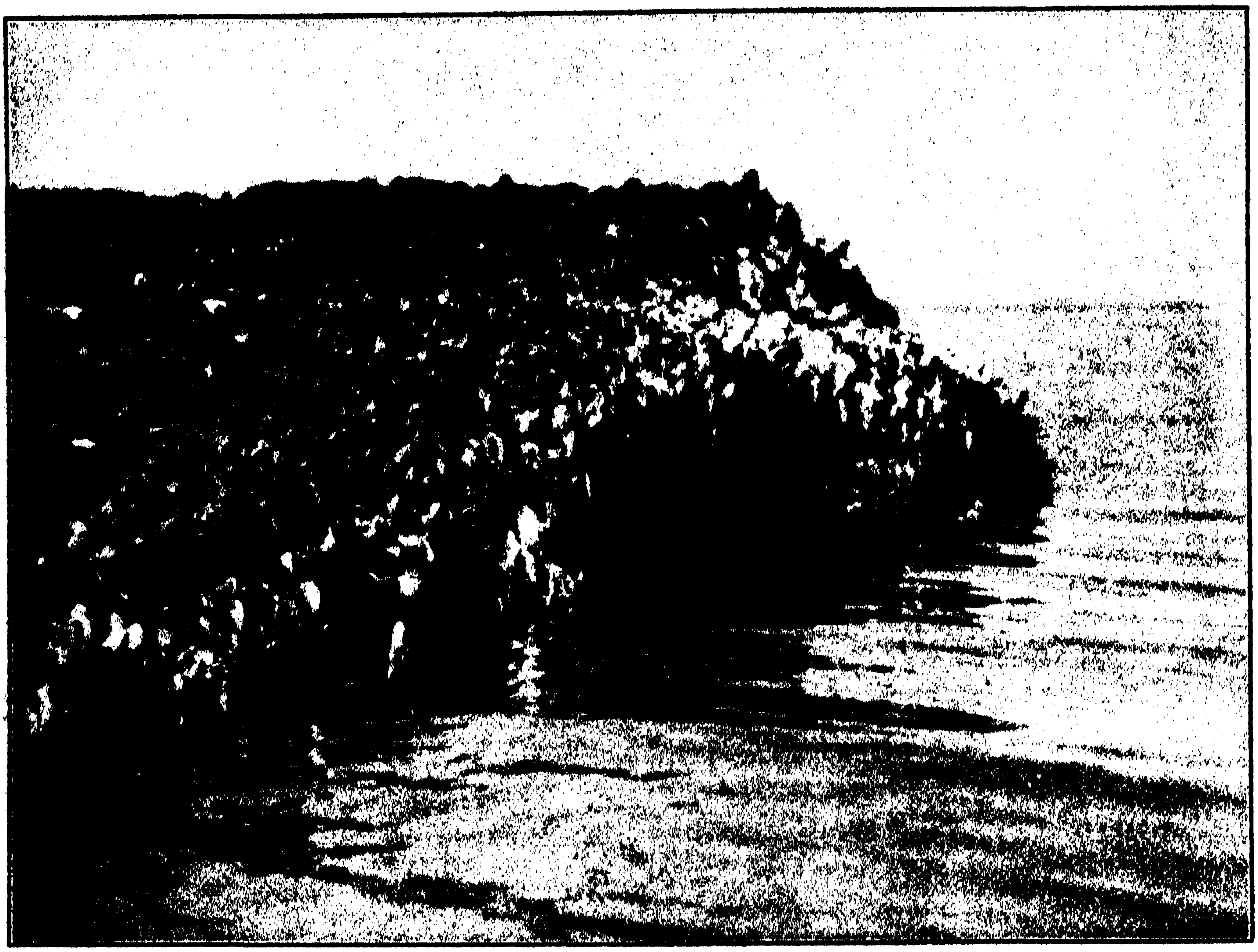


A NATURAL OYSTER REEF ON THE COAST OF SOUTH CAROLINA

A NATURAL OYSTER REEF ON THE COAST OF TEXAS

with very few touching each other. In oyster culture and oyster farming this interesting attachment or setting period in the life of the oyster is of prime importance. Man has taken advantage of this habit by placing old shells and other suitable objects in the water to which the oyster larvae readily attach themselves, and thereby he is able to collect and save vast numbers that would otherwise be lost. By placing shells on firm bottoms near the adult oysters or the natural beds he is able on the grounds he has prepared to obtain a considerable crop of seed oysters. From the first experiments made with the planting of shells in East River, N. Y., in 1855, the practice of oyster culture has grown steadily until at the present time over half of the oysters produced in this country come from privately owned and operated artificial beds. Beginning in the shoal waters along shore, the oyster growers have extended their operations into the deep open waters of Long Island Sound and Chesapeake Bay, converting thousands of acres of useless bottom into valuable food-producing areas. The modern oyster farmer, after acquiring many acres of suitable submerged bottom, conducts his operations along the following lines:

The grounds are carefully cleaned by dredging from them old shells, débris and natural enemies of the oyster, such as starfish, conchs and drills. On part of the grounds adult oysters are planted for growing purposes and also to serve as a spawning bed. In the early summer just previous to the time of spawning, thousands of bushels of old oyster shells from the shucking houses are planted on the grounds in the vicinity of the spawning beds; usually from five



PORTION OF AN OYSTER REEF ON THE COAST OF GEORGIA

hundred to one thousand bushels are used per acre. After the shell planting is completed the beds are left undisturbed for the remainder of the summer, the oysterman spending most of his time overhauling his boats and equipment. In the early fall an inspection of the shells is made to determine how heavy a crop of seed oysters has become attached to them.

If there is no danger of this new crop being buried or washed ashore by the fall and winter storms, they are left there until spring, at which time they are transplanted to the growing grounds. The growing grounds are generally located in deeper water and are known to be areas unfavorable for oyster reproduction so that oysters placed there are not covered and overcrowded by successive generations. On these grounds the seed oysters are given ample room for growth and reach marketable size in from two to five years, according to the locality in which they are grown.

The oyster farmer from years of experience has learned that not only are some areas favorable for collecting seed and others for growing the oysters, but that still others are excellent for fattening them. From six months to two years previous to the time of marketing, the oysters are placed on these fattening grounds, where with clean water and an abundance of food they become fat, tender and rich in vitamins and mineral salts.

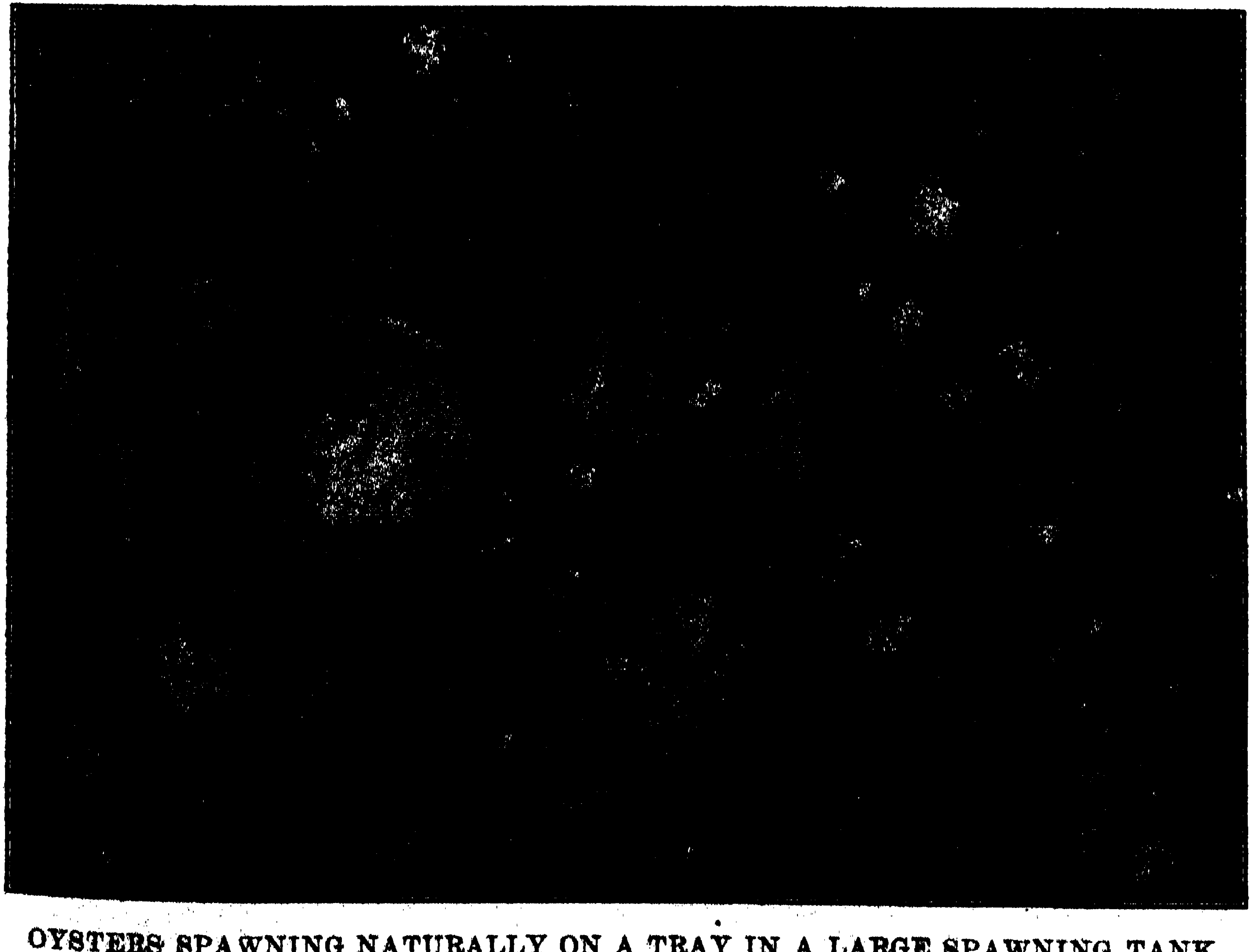
The oyster in feeding opens its shell, creates a current of water through the gills, and filters from the water passing through thousands of minute plants called diatoms, which are its principal food.

By means of a new apparatus invented in the laboratory of the Bureau of Fisheries, it has been possible to measure accurately the amount of water which the oyster drinks. Feeding for about twenty hours a day, the oyster uses approximately three quarts of water per hour at a temperature of 70°, or, in other words, fifteen gallons per day, from which it extracts more than 99 per cent. of the suspended material and food particles.

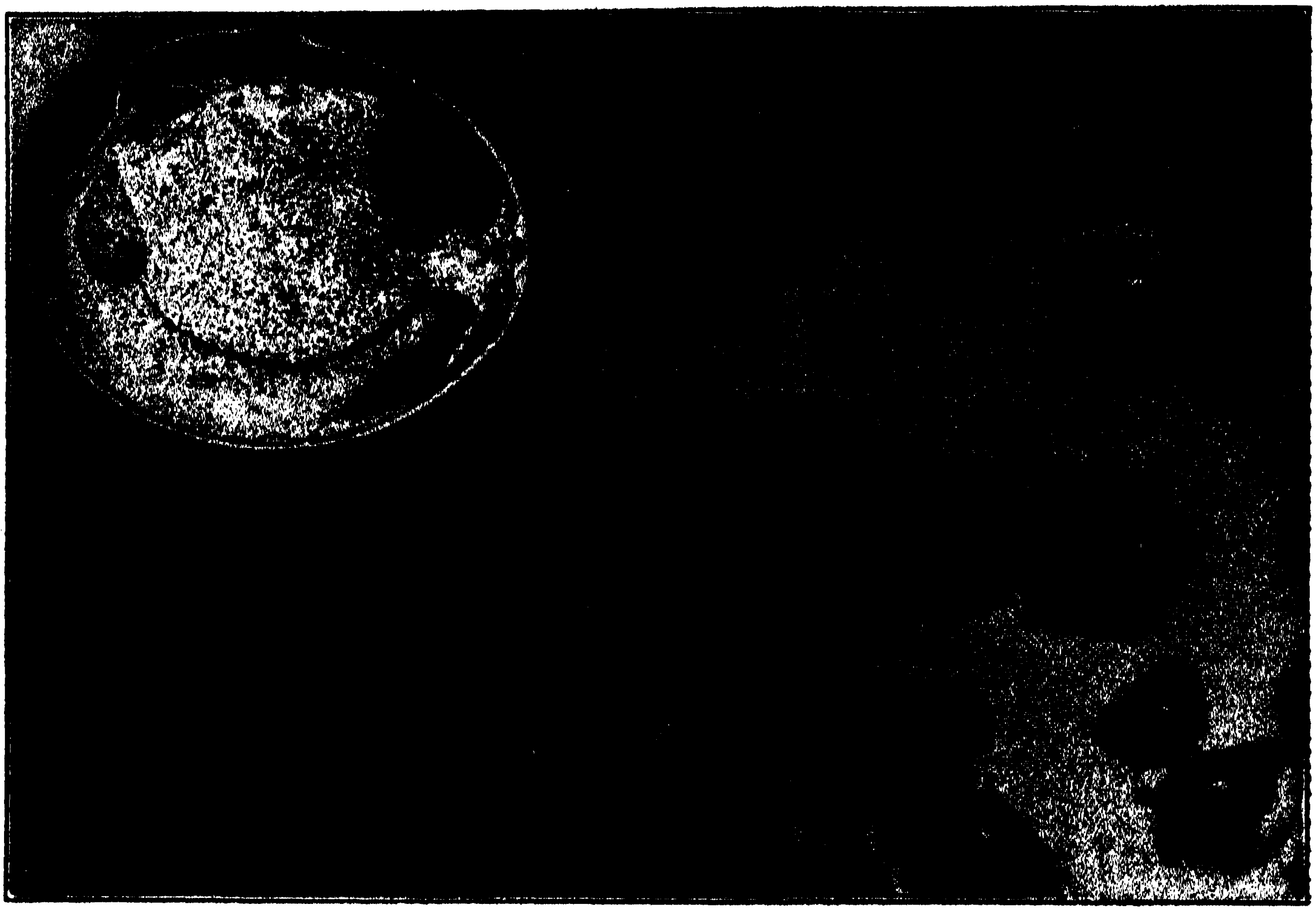
To show the magnitude of this process, let us make the following comparison: The District of Columbia uses sixty-five million gallons of water daily, yet this amount would be consumed in the same period of time by the population of an oyster bed only one tenth the size of the White House grounds. Many of our natural oyster beds which are as large as the tidal basin consume daily three thousand times as much water as is used by the entire District of Columbia.

As the temperature of the water becomes lower in the fall and winter the feeding activities of the oyster become less, until at a temperature below 44° it ceases to take in water and goes into a state of inactivity or hibernation. This period of hibernation lasts until the water warms up again in the spring, when the oyster resumes feeding.

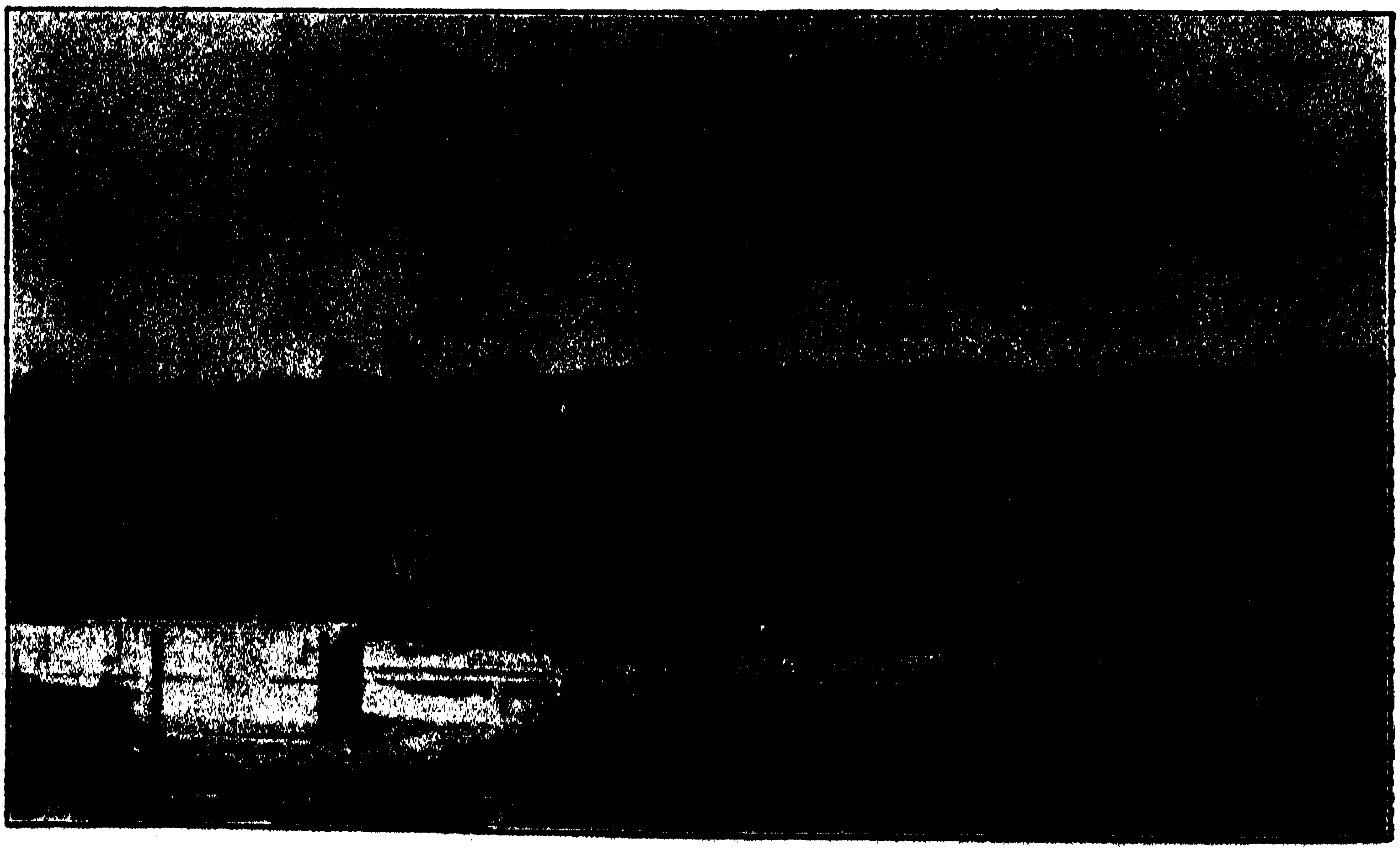
The oysterman, in gathering his crop in the cooler weather from his selected maturing beds, brings the oysters to market when they are in the best possible condition. The chief method employed in taking the oysters from the beds is the use of a dredge which is dragged over the bottom. Each gasoline- or steam-driven boat usually operates from two to four dredges, with which it is capable of gathering from one to five thousand bushels of oysters per day.



OYSTERS SPAWNING NATURALLY ON A TRAY IN A LARGE SPAWNING TANK



QUAHOG SHELL TO WHICH THOUSANDS OF YOUNG OYSTERS (SPAT) ARE ATTACHED, AND A PORTION OF THE SHELL ENLARGED, SHOWING THE INDIVIDUAL YOUNG; GREAT SOUTH BAY, LONG ISLAND



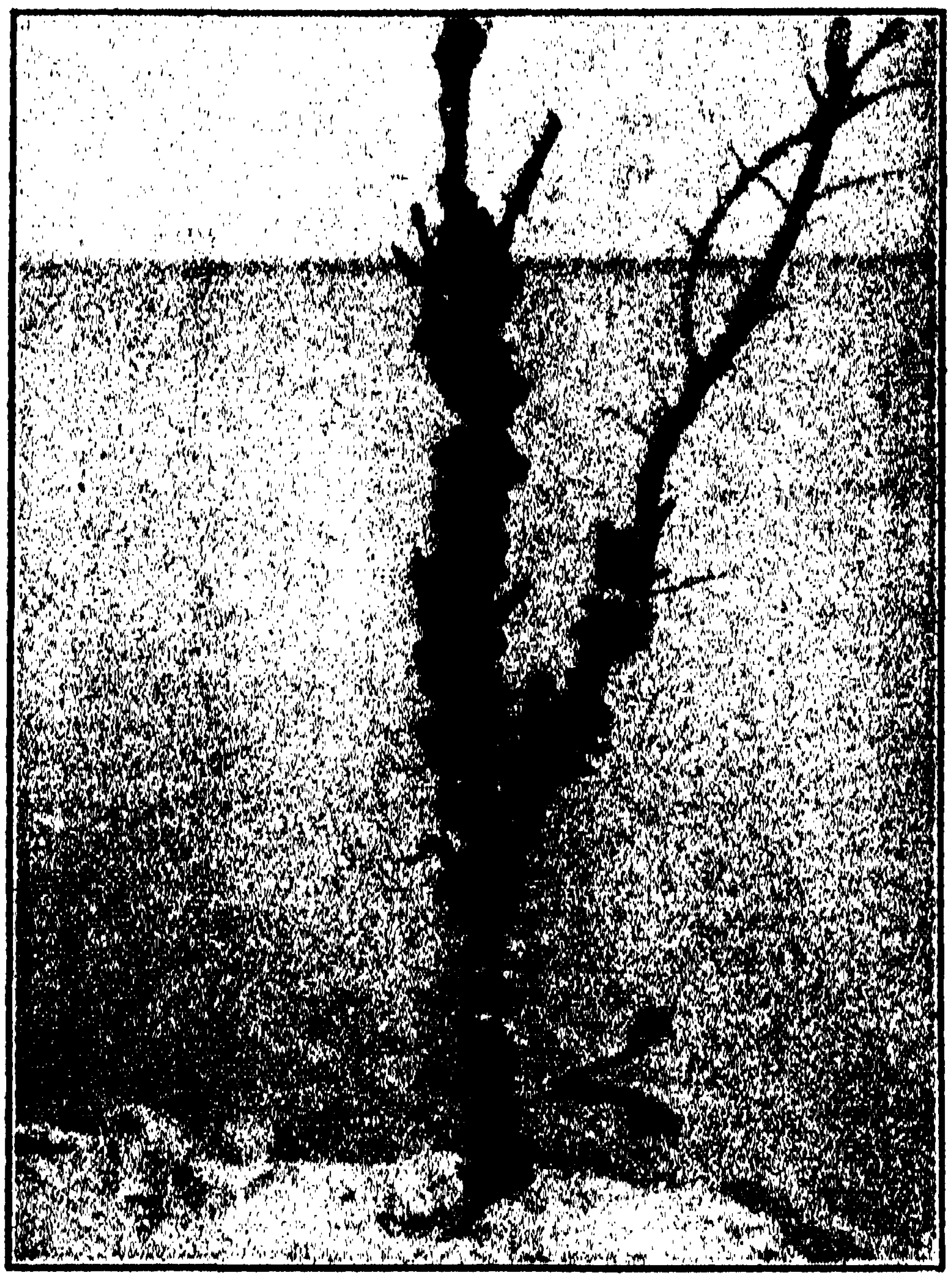
A BOAT LOAD OF BRUSH PREPARED FOR THE CATCHING OF OYSTER SPAT; GREAT SOUTH BAY, LONG ISLAND

Between the shell-planting and the harvest, an interval of from two to five years, the oyster farmer assumes many hazards. In northern waters, with unfavorable weather conditions, he often fails to obtain a crop of oysters on the material he had planted; while in the South Atlantic and Gulf waters the crop is often so heavy that the oysters are overcrowded, poorly shaped, and suffer from lack of food. They are never safe from their natural enemies, one of the worst of which is the common starfish, which wraps its arms about the oyster, pulls the shells apart and, by turning its stomach inside-out, absorbs the oyster as it lies within the shell. The planter fights the starfish by dragging over the beds large mops of rope yarn. The starfish become entangled in the threads and are drawn up and killed by plunging the mops into vats of boiling water placed on deck.

The drill, or borer, a little marine snail, is another destructive enemy, which, using its tongue like a rasp, bores a hole through the shell and licks the delicious meat within. In southern waters schools of drumfish invade the beds and feed on the oysters by grinding them to fragments between their powerful teeth. Flood waters from the land and storms rolling in from the sea take a heavy toll, either killing the oysters by subjecting them to fresh water for prolonged periods, or burying them in the bottom by powerful wave action.

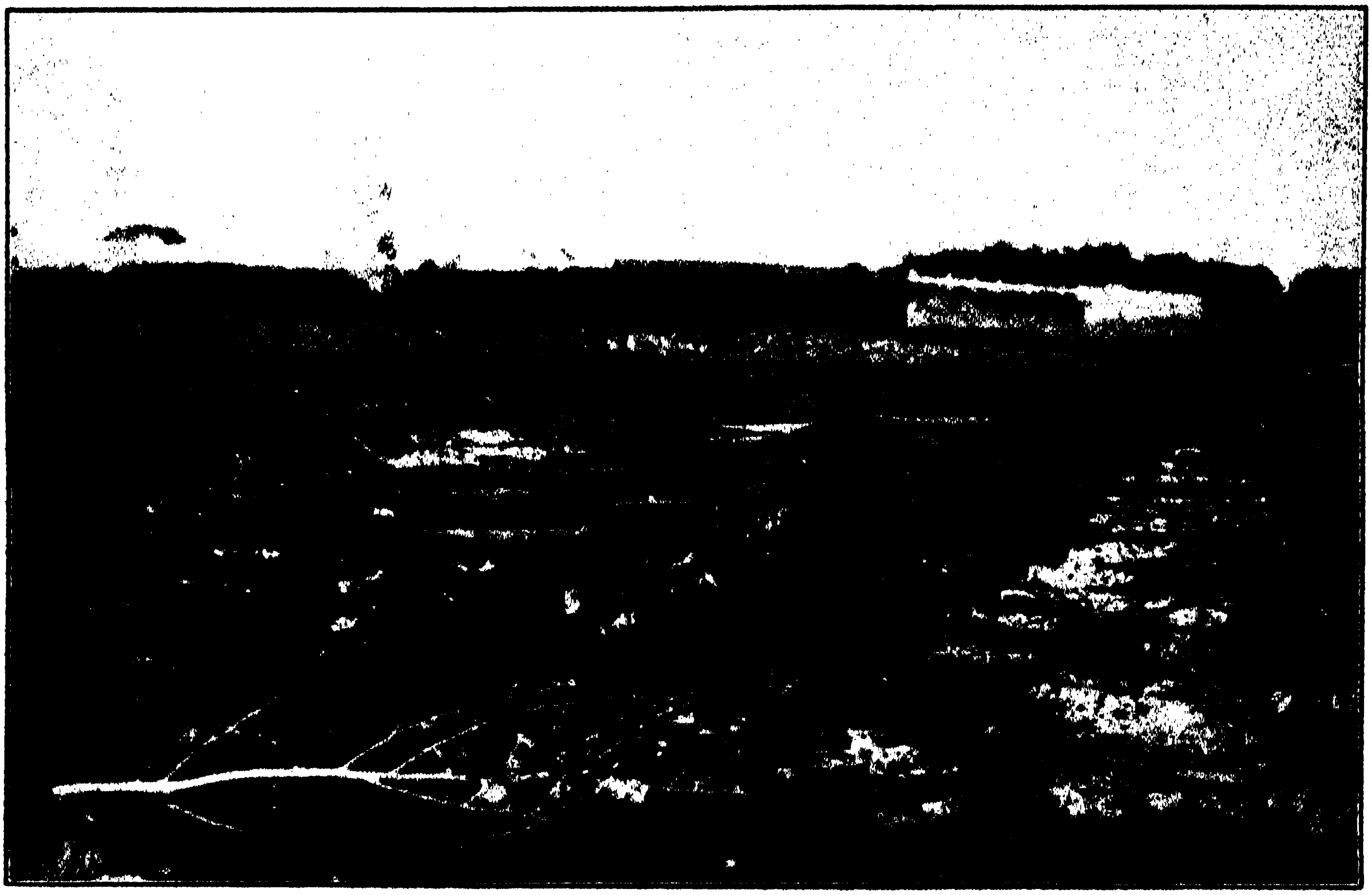
In spite of the extensive development of oyster culture, these and various other factors have brought about a constant depletion of the oyster beds, both natural and cultivated, resulting in an alarming decline in the productiveness of our great oyster fisheries.

In order to determine new methods for maintaining and increasing the supply of oysters, extensive studies and experiments have been made by the Bureau of Fisheries in Massachusetts, Connecticut and various other coastal states. Two methods have been developed for increasing the production of seed oysters, since the decrease of these has been one of the principal causes of the decline of the industry.



OYSTERS ON A TREE; YOUNG OYSTERS ATTACHED TO A BIT OF BRUSH; SOUTH CAROLINA

One method consists in the use of brush for collecting the seed oysters on the tidal flats, or, in other words, the growing of oysters on trees. A short time before the oysters spawn branches from four to eight feet long are forced into the bottom and arranged in conical stacks. In a week or two the oyster larvae become attached to them, thousands covering each branch. The following spring the branches are either transplanted to growing grounds, or the oysters are detached from them and planted singly. There are many advantages in using brush, chief of which are that it utilizes soft mud bottoms and that in a

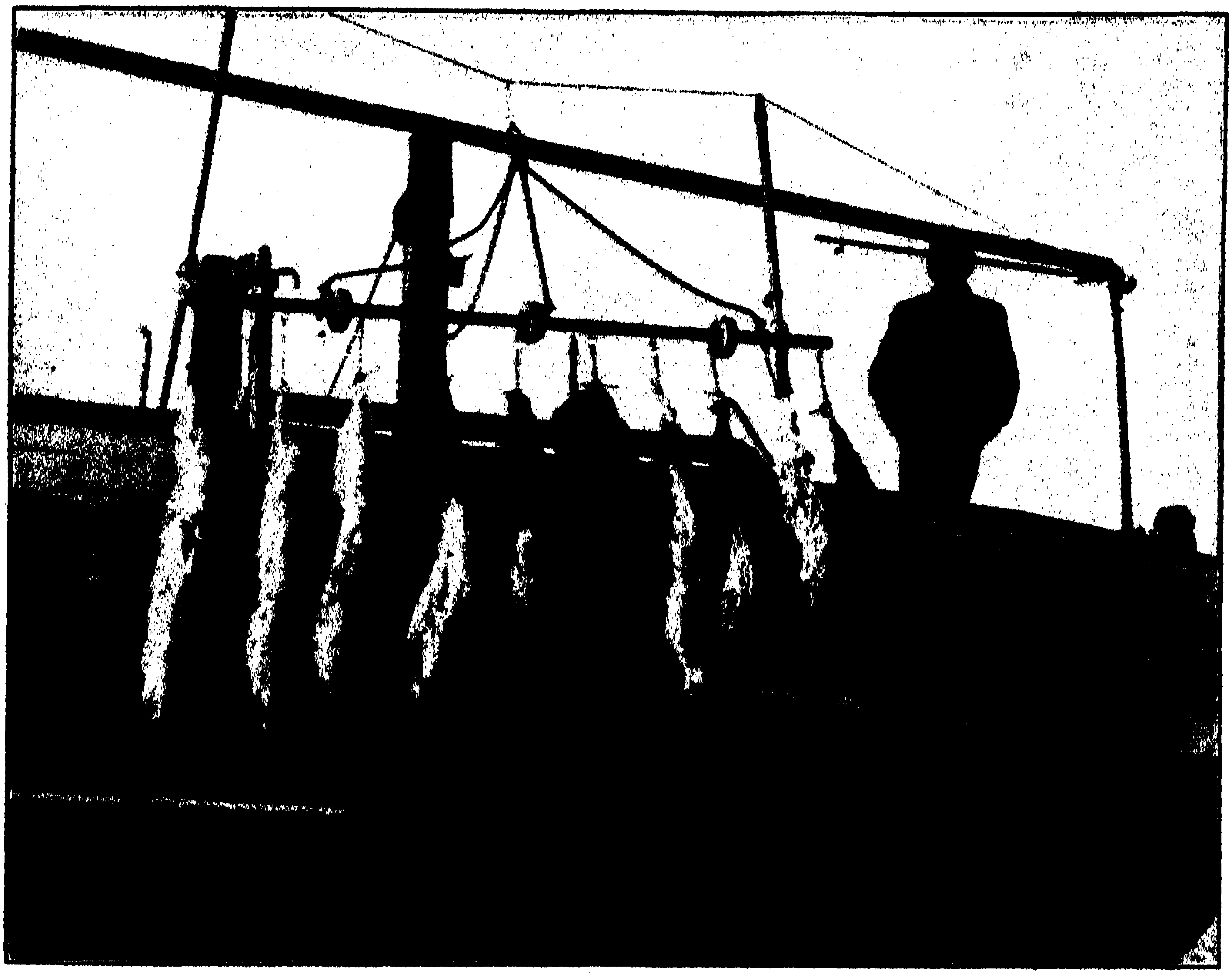


CRATES FILLED WITH OYSTER SHELLS, PREPARED FOR THE COLLECTION OF YOUNG OYSTERS, OR SPAT

year it will disintegrate or be destroyed by shipworms, so that the seed oysters attached to it break apart as single individuals.

The idea of using brush is not new, as it was first used by the Romans about the time of Julius Caesar, and the method is still practiced on the coast of Italy and in other parts of Europe. Also in Australia, the tidal flats are covered with mangrove sticks, while in Japan the grounds appear like forests of bamboo heavily laden with oysters. The birch and oak brush plantings which were made in Milford, Connecticut, and in Georgia, were successful, and clearly indicate that in the United States, especially in southern waters, brush can be used on a practical commercial scale and will give excellent results.

During the past summer an entirely new method was developed for the control and production of seed oysters in northern waters. It consists essentially in the establishment of spawning beds in bays, harbors and river mouths, and the planting nearby of crates filled with shells for collecting the oyster seed. The crates were constructed of spruce lath, were triangular in shape and held two bushels of shells. In Milford Harbor, Connecticut, and Wareham River, Massachusetts, four hundred crates were set out and these collected over five million seed oysters. The advantages of using the crates are: that eight or ten times more seed oysters can be produced on a given area than by the ordinary methods of shell planting and that they can be placed on barren mud flats and sand bottoms or directly over the spawning



A STARFISH MOP, USED FOR THE REMOVAL OF STARFISHES FROM OYSTER BEDS; MILFORD, CONNECTICUT

beds, thereby obtaining the maximum use of the limited inshore areas.

Further studies of the oyster, its life history and environment are being made so that the oyster farmer, like the agriculturist, can control increase and protect his crop by the application of scientific methods.

WATCHMAKERS AND INVENTORS[1]

By CARL W. MITMAN

U. S. NATIONAL MUSEUM

In one of our modern encyclopedias appears the statement that more basic inventions, except those in electricity and industrial chemistry, are the results of efforts of watch and clock makers than of any other professional group. It is a statement that I can hardly doubt, for I could consume much time by giving simply an alphabetical and chronological list of the names of inventors whose basic mechanical experience was that of watchmaking.

We are all pretty generally agreed that the world to-day is a rather pleasant place to live in, particularly the United States, and were we to make a search for the causes back of our present standards of living we would eventually find three basic ones; first, our wealth of natural resources; second, our intensive application of mechanical power and tools in the exploitation of these resources; and third, the thorough development of our transportation systems for the distribution of commodities. Our resources were placed here during the formation of the earth and simply awaited discovery by our ancestors, but it was James Watt by his invention of the separate condenser who made possible the development of the true steam engine, which, in turn, brought about what is sometimes called "the industrial revolution," from which time mechanical power and mechanical contrivances gradually replaced hand power and hand appliances.

Whether the story of Watt and the teakettle is authentic or not is immaterial. We know that his father's business of selling ship's supplies in Glasgow, Scotland, did not appeal to young Watt, and he went to London and paid the sum of $500 a year to a master of the Watchmakers' Guild for instruction in the watchmaker's art. After an apprenticeship lasting two years he had advanced on his own ability to such an extent that he set up shop in Glasgow as an instrument maker. His chief work was that of repairing and constructing the scientific instruments used at the University of Glasgow, and on one occasion a working model of a Newcomen atmospheric engine was sent to him for repairs. This was the first steam engine that Watt had ever seen, and it was while working on it that he made his discovery that by the use of a separate vessel for condensing the steam greater efficiency and more work could be obtained from the Newcomen engine.

As we look back to-day, we can see that the most direct effect of Watt's invention was the gradual development of machines to replace hand labor, giving employment to many where formerly there were openings for a few, with the result that in a comparatively short time the production of industrial commodities increased. This increase, in turn, brought to light the shortcomings and the inadequacy of the prevailing means of transportation. A few fearless men in England boldly suggested the use of steam engines on wheels as a solution to the problem and proceeded to build engines to prove their claim. Richard Trevithick was one of these individuals, but the locomotives that he built were unable to stand the test as to their economic value.

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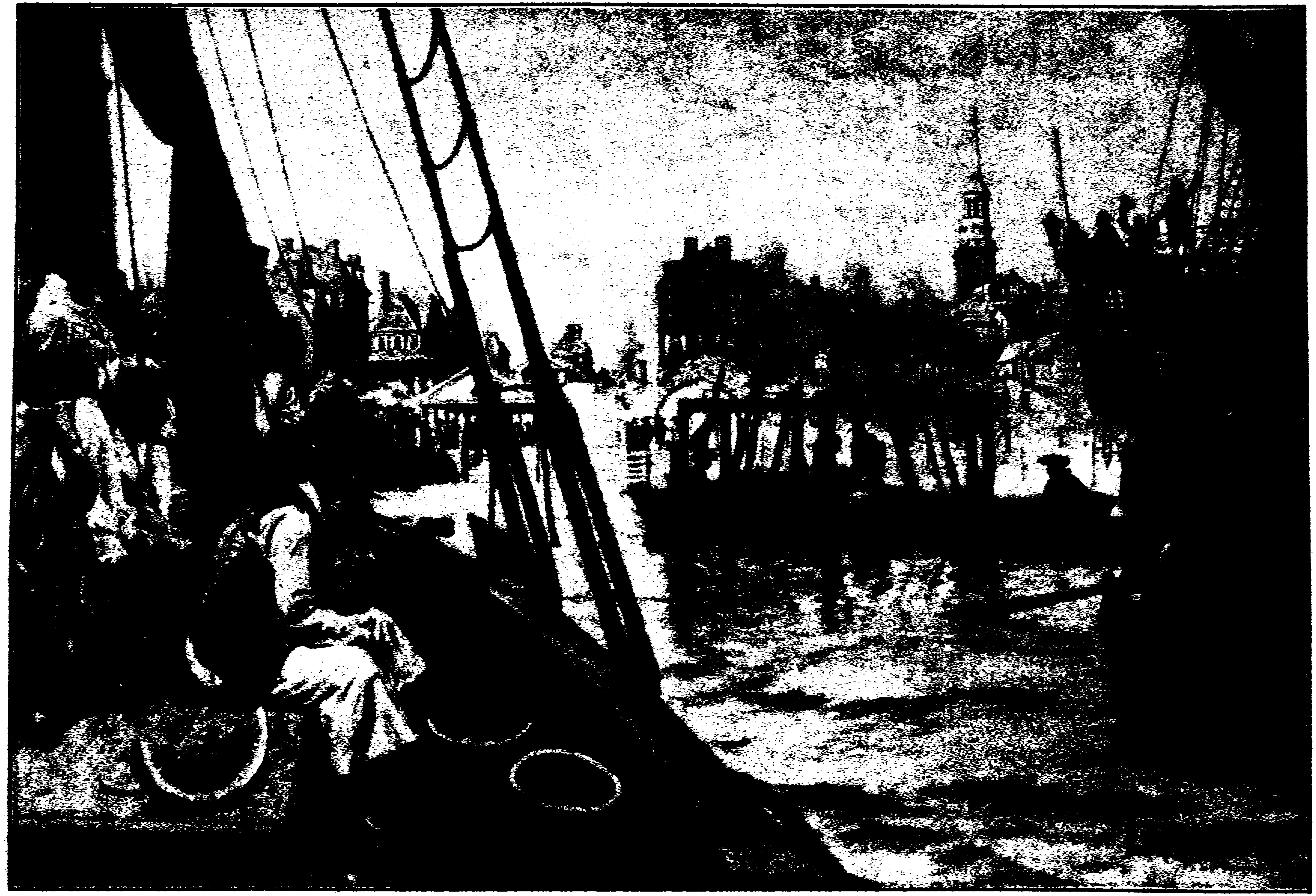
[1] One of the Smithsonian series of radio talks arranged by Mr. Austin H. Clark and given from Station WRC, Washington.

JAMES WATT

INVENTOR OF SEPARATE STEAM CONDENSER IN 1769.



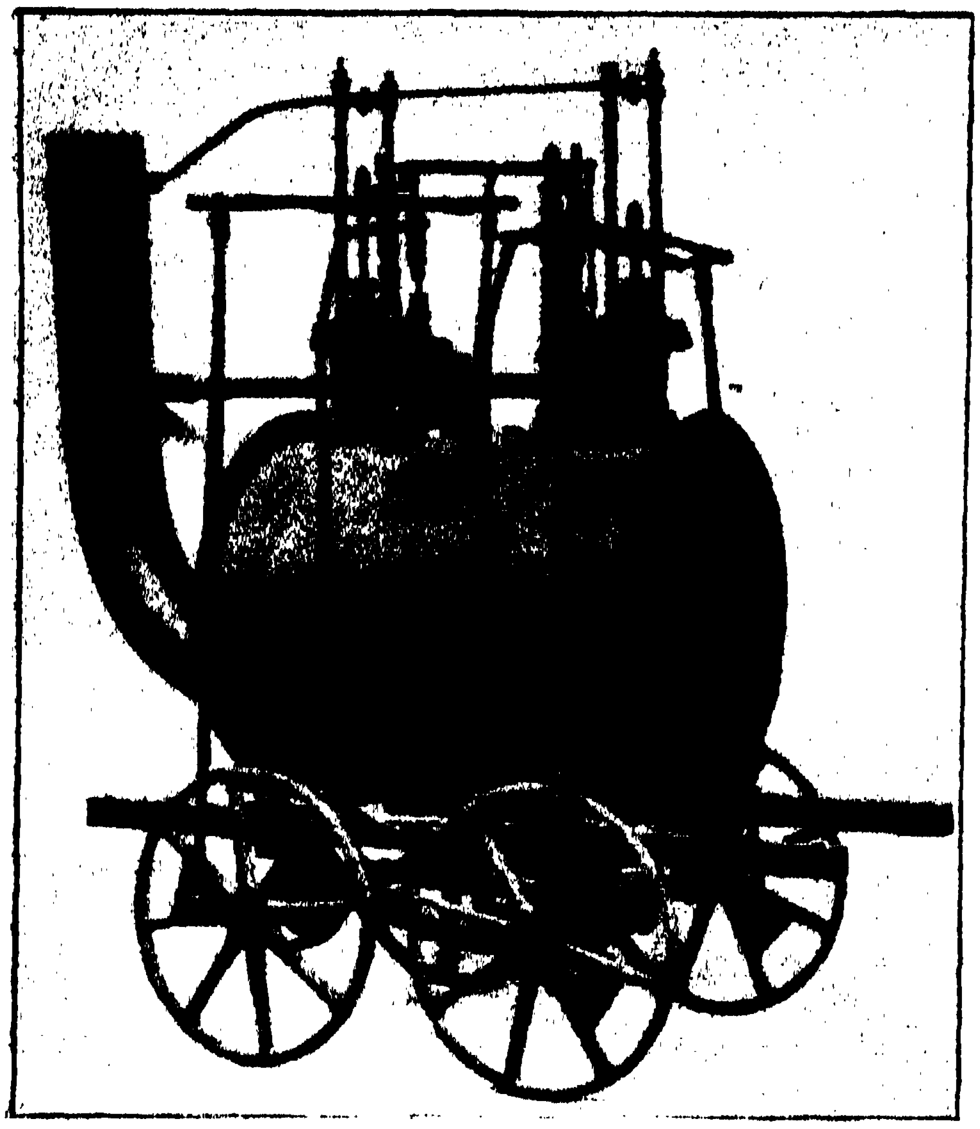
From a painting by Clyde O. DeLand

THE TRIAL OF JOHN FITCH'S STEAMBOAT ON THE DELAWARE RIVER AT PHILADELPHIA IN 1786

Another Englishman who believed as did Trevithick was George Stephenson, and it was he who constructed a locomotive which definitely proved the superiority of the steam engine over the horse and brought about the beginning of the "iron horse era." Stephenson received his early training about the coal mines in the north of England, first as a pumping engine man and later as an engineer. His wages were very low; he appreciated the value of an education which he did not possess; and he was most anxious that his only son should be educated. He secured whatever extra work and money he could, which came mainly from the repair of the timepieces of the townspeople in the several towns in which he lived. It was through the experience which he thus gained, combined with his experiences with the Newcomen and Watt pumping engines, that he was enabled to develop and construct in 1825 the locomotive "Locomotion," the first practical steam locomotive in the world.

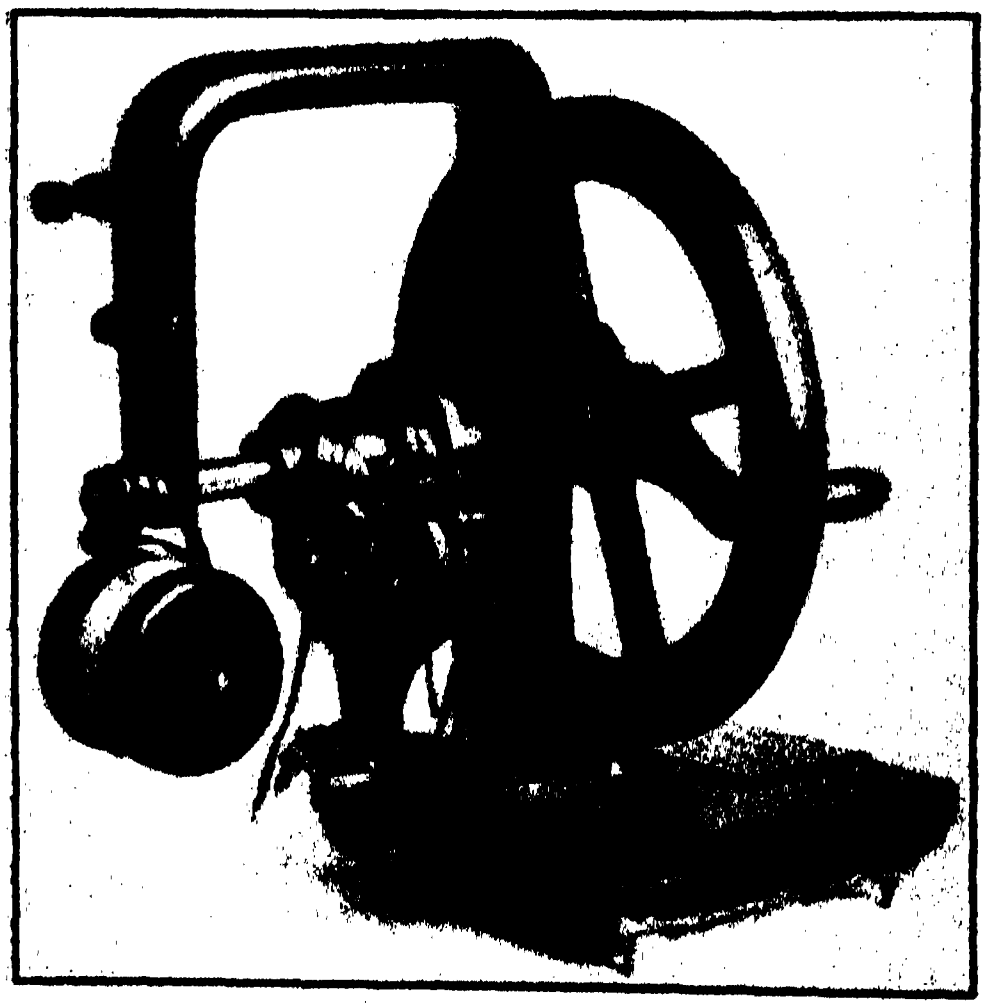
Several years ago I came across a little squib which illustrates rather well the relationship which now exists between the manufacturing and transportation industries. It went something like this: "My son, the chickens we eat all come from little eggs." "That's funny," said the son, "I always thought it was just the reverse." In other words, the manufacturer to-day must have a transportation service and the transportation industry must have goods to carry. Both of these industries received their impetus from the discoveries and work of Watt and Stephenson, whose chief training was that of watchmaking, and both have advanced and developed materially through the discoveries and efforts of men of like training.

It is generally conceded that many new discoveries are the product of several brains, and while this may be true in our day of almost instantaneous communication, it can hardly be said of the fifty-year period following the signing of the Declaration of Independence. Then it was physically possible for neighbors, as it were, to be working on and developing the same idea without any knowledge, one of the other. Knowing what we do to-day, we are prone to be rather hard on our forefathers, who at the beginning of the nineteenth century looked with scorn and derision upon the men who advanced what the majority thought were impossible ideas, but I doubt whether much of this skepticism of new ideas has entirely disappeared even today; in proof of which let me ask what you who were twenty-one or over in 1900 thought of the men who were interested in flying machines. It was skepticism such as this that undoubtedly robbed the United States of the credit of the invention of the locomotive, for, as early as 1786, Oliver Evans, of Philadelphia, asked the legislature of Pennsylvania, and later that of Maryland, for the sole right to operate carriages propelled by steam on the highways. Separated as he was by thousands of miles of water from England, it is not hard to believe that his work was original with him and not an improvement on something that had been developed elsewhere. The Pennsylvania legislature refused Evans' request, but the Maryland legislature granted it on the ground that no harm could be done anybody. But with this monopolistic grant no capital was obtained, even after he had built a four-horsepower steamboat in 1804, put wheels under it, and ran it through the streets of Philadelphia as proof of the soundness of his ideas, and had gone so far as to bet $3,000 that he could build a steam wagon to run on a level road against the fastest horse any one could produce. His entreaties fell on deaf ears, and it required the importation of a locomotive from England twenty-five years later to convince a very few that the steam locomotive not only could move without being



ORIGINAL MODEL OF A LOCOMOTIVE

CREDITED TO OLIVER EVANS, OF PHILADELPHIA, IN 1804.

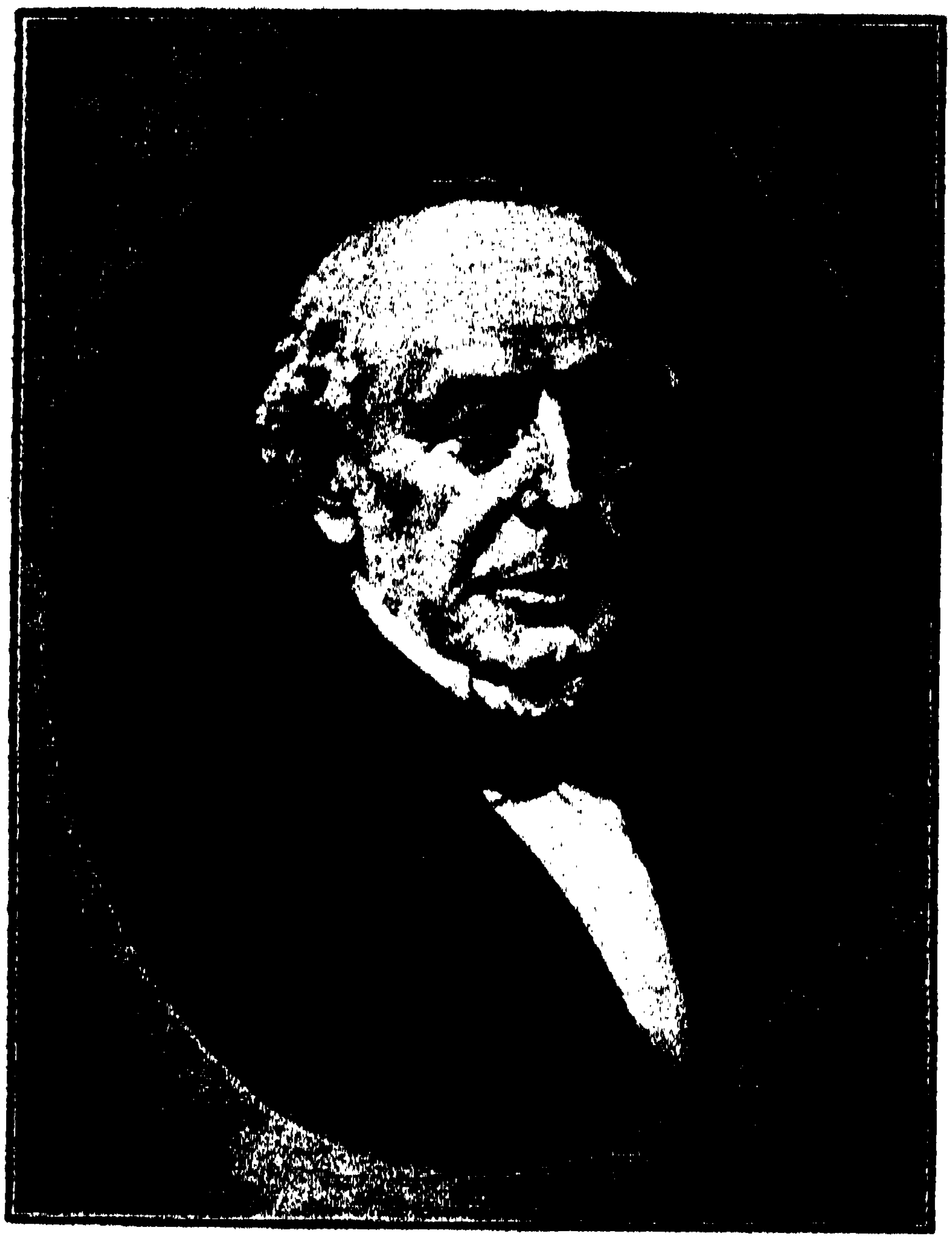


ELIAS HOWE'S SEWING MACHINE, 1846

pulled by a horse but that it could transport merchandise more cheaply than the horse.

The constant hammering which the public generally in our own country received from such men as Evans, Dearborn, Stevens and Cooper brought about gradually the acceptance of the idea that the railway was the best means of obtaining better transportation. But the people were not convinced that the steam locomotive should be the power used. Several of the railroads, chiefly the Baltimore & Ohio and the South Carolina, had already received their charters and were planning to install horse-drawn carriages, when, as a result of the successful trials on the Baltimore & Ohio tracks of an experimental locomotive, built by Peter Cooper in 1829, he being financially able to prove his assertions as to the steam locomotive, the Baltimore & Ohio changed its plans and offered a prize of $4,000 for a steam locomotive capable of pulling fifteen tons at the rate of fifteen miles an hour. In due time the company received five locomotives, two of which were made by watchmakers in Philadelphia, namely, Stacey Costell and Ezekial Childs.

The radical policy of the Baltimore & Ohio Railroad in ordering a steam locomotive, coupled with the fact that the Delaware & Hudson Company had ordered four locomotives from England, aroused more and more public interest in the steam locomotive, and in 1829 the Philadelphia Museum endeavored to satisfy this interest by exhibiting a working model of a locomotive. The museum secured the services of Matthias W. Baldwin to build it. Baldwin was a watchmaker and just prior to this time had enlarged his establishment to manufacture bookbinding tools and machinery for calico printing. He had also just completed a miniature steam engine. The model locomotive he built for the museum drew two miniature coaches on a circular track. As a result of this work and the skill which he showed in the construction of the model, the officials of the newly organized Philadelphia, Germantown & Norristown Railroad Company sought Mr. Baldwin's

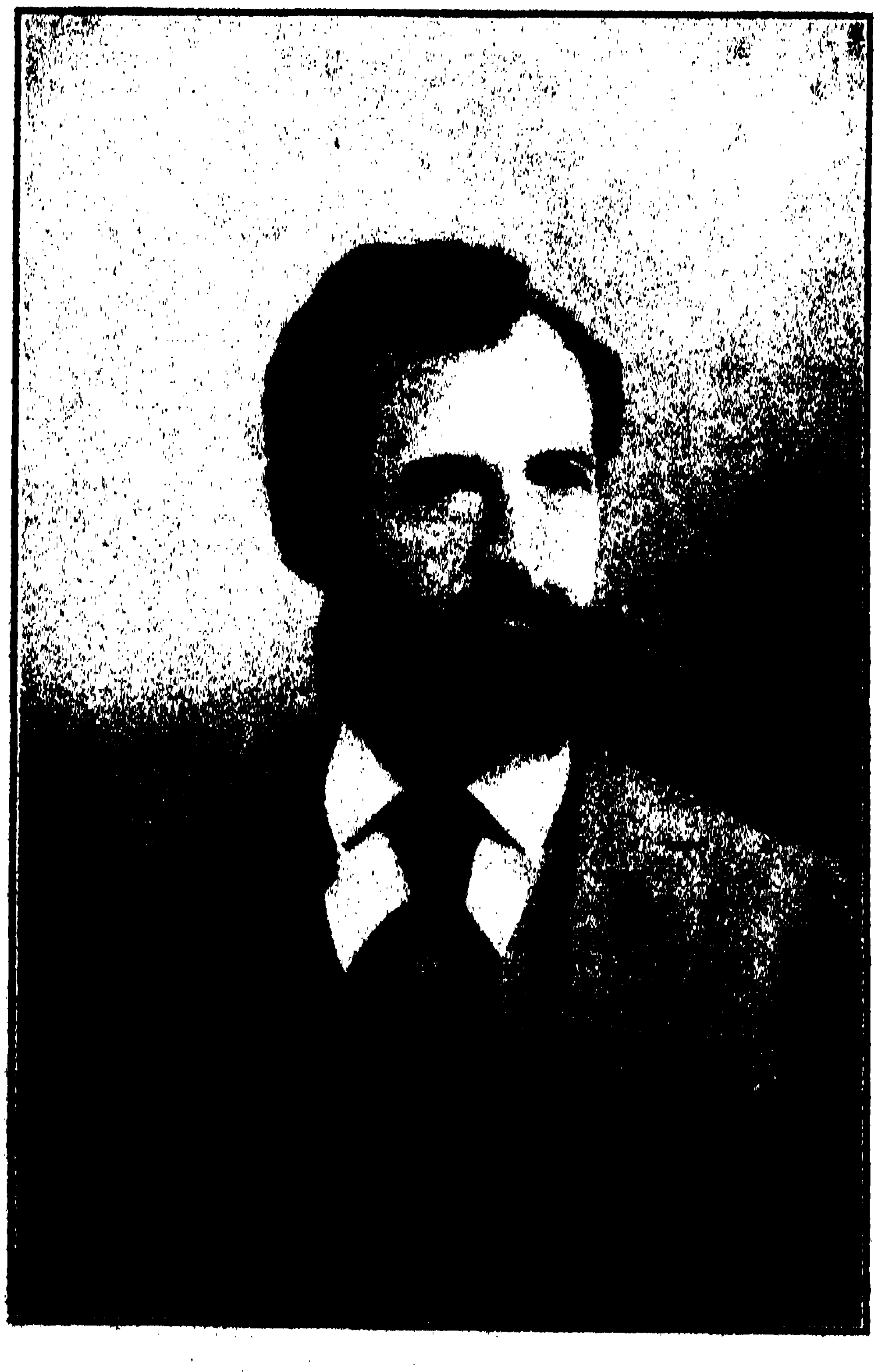


MATTHIAS W. BALDWIN
FOUNDER OF THE BALDWIN LOCOMOTIVE WORKS AT PHILADELPHIA IN 1832.

services in the construction of a full-sized locomotive for their railroad. He accepted and built "Old Ironsides," which was tried out in the latter part of 1832, and its trial marked the first movement by steam on a railroad in the state of Pennsylvania. Baldwin thereafter continued building locomotives and organized the well-known Baldwin Locomotive Works.

About the time Oliver Evans was pleading for capital to build his steam-propelled road vehicles, John Fitch was pleading for capital to build a steamboat. When quite young he left home and apprenticed himself to a Connecticut watchmaker. This man, however, was of the type who believed that to teach an apprentice anything would decrease the amount of work accruing to himself, and accordingly he kept his tools under lock and key and did his repair work as far away from Fitch as possible. It was only by stealing the tools when the master was away and by slyly watching him work that Fitch acquired all his knowledge of mechanics. Apparently it was sufficient, however, for a few years later in 1786, through his own efforts, he accumulated sufficient money to build a steamboat which made regular trips on the Delaware River between Philadelphia and Trenton.

The establishment of the new industrial order early in the nineteenth century brought with it vast opportunities for the application of inventive talents and the watch and clock makers are well represented in the real inventions which were made during this century. It was Joseph Rogers Brown, a New England clockmaker, a number of whose tower clocks are still in use after seventy-five



OTTMAR MERGENTHALER
INVENTOR OF LINOTYPE, 1883.

years, who in 1850 invented the first automatic machine in the United States for graduating rules and which is still in use, meeting all the requirements of modern accuracy. He too, in 1852, introduced the vernier caliper reading to a thousandth of an inch and built the first universal grinding machine. While apprenticed to a Boston watch and instrument maker, Elias Howe overheard a customer remark that a fortune awaited the man who could invent a sewing machine, and four years later in 1846 he received his sewing machine patent.

The reams of printed matter available to us to-day, whether books, magazines or newspapers, were made possible by a citizen of the United States, Ottmar Mergenthaler, who emigrated from Germany in 1872 with nothing but his completed apprenticeship as an expert watchmaker and thirty dollars in cash. Twelve years later he successfully demonstrated his new idea of setting type mechanically and subsequently offered to the world the linotype.

I believe you will agree that the brain of the watchmaker, as a class, is wonderfully versatile. As a further proof of this, let me close with the epitaph which a watchmaker composed for himself more than a hundred years ago. Some one else, of course, filled in the date of his death.

Here lies in a horizontal position the outside case of
George Routledge, Watchmaker.
Integrity was the mainspring and prudence the regulator of all the actions of his life;
humane, generous, and liberal,
His hand never stopped till he had relieved distress.
So nicely regulated were his movements that he never went wrong, except when set going by people who did not know his key.
Even then he was easily set right again.
He had the art of disposing of his time so well, that his hours glided away, his pulse stopped beating,
He ran down November 14, 1801, aged 57,
In hopes of being taken in hand by his Maker,
Thoroughly cleaned, repaired, wound up, and set going in the world to come, when
Time shall be no more.

TYNDALL'S EXPERIMENTS ON MAGNE-CRYSTALLIC ACTION[1]

By Sir WILLIAM BRAGG, F.R.S.

IN 1845, Faraday made the surprising discovery that the vast majority of substances, not merely iron, nickel and cobalt, are affected by a magnet; and showed also that the action is repulsive quite as often as attractive. Faraday's results excited the greatest interest and were the starting-point for many other researches. In fact, they paved the way for the work of Thomson and Maxwell, who came thereby to the establishment of the laws of electromagnetism. Among the many workers who followed Faraday was Tyndall, who made certain interesting discoveries relating to the behavior of crystals in the magnetic field.

A very lively discussion sprang up as to the mode of interpretation of the new discoveries, particularly that of the so-called diamagnetism. On one hand, Faraday was satisfied that he could describe them in terms of his "lines of force": the majority, including Tyndall, referred everything to the existence of poles, magnetic and diamagnetic. Tyndall's experimental work, and the consequences which he drew from it, were devoted to the support of these views. When Faraday's conceptions prevailed it became clear that Tyndall's interpretation of his own experiments must have been incorrect. His collected account of his researches, published in the well-known "Diamagnetism and Magne-crystallic Action," never became a link in the chain of argument.

The recent analysis of crystal structure by means of X-rays throws some new light on those experiments of seventy years ago. We can see more clearly where Tyndall's conclusions were in error. But at the same time the experiments of Tyndall are seen to be closely related to a modern research of immense importance, that of the effect of stress on the constitution and physical properties of materials.

FARADAY'S FIRST OBSERVATION OF DIAMAGNETISM

On September 13, 1845, Faraday made one of his most important discoveries, that of a relation between magnetism and light. He found that when plane polarized light was made to traverse a piece of his "heavy glass," a borosilicate of lead, in a direction coinciding with that of lines of magnetic force, the plane of polarization was rotated. He had thus been successful in showing that the action of a magnet did not require the cooperation of a magnetic substance such as iron for its manifestation, but might be directly connected with a substance of a different kind, namely, glass, and a different activity, namely, light. In the following months he tried to find some other connection between magnetism and this glass. He floated his glass on a liquid and tried whether he could move it by a magnet, without result. But on November 4 he succeeded in his search.

> The bar of heavy glass, 1 6/8 of an inch long and . . . [2] of an inch square, was suspended by cocoon silk in a glass jar in principle as before and placed between the poles of the last magnet. When it was arranged and had come to rest I found I *could* affect it by the magnetic forces and give it position. Thus touching diamagnetics by magnetic curves and observing a property quite independent of light by which we may probably trace these forces into opaque and other bodies as the metals, etc.
>
> If 1 was the natural position on making the poles magnetic the glass swung into position 2 and on to position 3. If contact was united after 2 the tendency to 3 was diminished, *i.e.,*

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[1] Discourse delivered at the Royal Institution on Friday, January 21, and printed in *Nature*.

[2] Not filled in, but from other notes we know it was half an inch square.

> was less than if there was no current. If whilst swinging contact of current was continued during vibration from 1 to 2 and broken from 2 to 3, then united from 3 to 2 and broken from 2 to 1 the bar was soon sent spinning round the whole circuit.

The word "diamagnetic" is here used to denote substances through which, on his views, magnetic lines were passing. It is not yet used as an antithesis to "paramagnetic." His new result obviously gave him intense pleasure, and in following it up he was so preoccupied that he did not even go to the meeting of the Royal Society on November 20, when his paper on the "Action of Magnets on Light" was read.

We can easily repeat the experiment, using a piece of the same glass taken from the store left by Faraday. It is not the actual piece, Number 174, as he tells us in his notes, for this can not be found. The glass turns slowly in the magnetic field, and its motions are obviously controlled by switching the current off and on. The glass tends to set itself *across* the lines of force running from pole to pole, not *along* the lines as a piece of iron would do; and obviously the effect is very small as compared with the violent movements of iron in the same circumstances.

The action may be described as a repulsion of the glass by the magnet; and sometimes the early workers on the subject constructed apparatus specially designed to show the repulsive effect more obviously, and to distinguish it from a mere turning action in a magnetic field, if indeed this could be done. We can illustrate this point, and at the same time the diamagnetism of bismuth, by using a piece of apparatus constructed by Tyndall.

Faraday's First Explanation of Diamagnetism

Faraday at first suggested that the diamagnetic effect was the antithesis of the ordinary magnetic effect. A piece of iron when placed between two poles became so magnetized that a south pole was developed upon it in that part which was nearest to the north pole of the inducing magnet and *vice versa*. Faraday's suggestion that the diamagnetic substance developed north and south poles where a magnetic substance would have developed south and north, respectively, was taken to be a satisfactory explanation. It was the constant endeavor of later experimenters to express their results in accordance with Faraday's hypothesis: even when development had reached a stage some distance ahead of that described in the original paper (*Phil. Trans.*, 1846, p. 21).

Faraday was himself the first to feel doubts as to the satisfactory nature of his explanation. His early results could conveniently be described as showing an exact antithesis between two classes; where one was attracted by a magnet, the other was repelled; where one set itself in a certain direction in the magnetic field, the other avoided that direction as much as possible. It seemed proper to describe them as being in exact antithesis to each other, and the word diamagnetism was adopted as a means of expressing the experimental result.

He prepared a list of substances which showed varying degrees of response to the action of the magnetic field, and the plan of the statement illustrates his first views ("Experimental Researches," Series XXI, No. 2424):

Iron
Nickel
Cobalt
Manganese
Palladium
Crown-glass
Platinum
Osmium
0° Air and vacuum
Arsenic
Æther
Alcohol
Gold
Water
Mercury
Flint glass
Tin
Heavy glass
Antimony
Phosphorus
Bismuth

It is to be observed that those preceding air and vacuum are to be considered above zero or magnetic, those succeeding, below zero or diamagnetic, which is meant to imply a true antithesis.

In December, 1845 ("Experimental Researches," Series XXI, No. 2429), Faraday writes:

> Theoretically, an explanation of the movements of the diamagnetic bodies, and all the dynamic phenomena consequent upon the actions of magnets on them, might be offered in the supposition that magnetic induction caused in them a contrary state to that which it produced in magnetic matter; *i.e.*, that if a particle of each kind of matter were placed in the magnetic field both would become magnetic, and each would have its axis parallel to the resultant of magnetic force passing through it; but the particle of magnetic matter would have its north and south poles opposite, or facing towards the contrary poles of the inducing magnet, whereas with the diamagnetic particles the reverse would be the case; and hence would result approximation in the one substance, recession in the other.

Even at that time, however, Faraday's views were not firmly established, and we may repeat an experiment of his which shows the nature of the contrary influences that were impressing him. A small glass tube filled with a weak solution of the magnetic substance iron sulphate sets itself axially between the magnetic poles; but if it is surrounded as it swings by a strong solution of the same substance, it sets equatorially. The tube appears to be magnetic as compared to air, but diamagnetic as compared to the strong solution.

Might not, on this analogy, all substances, and also air and vacuum, be magnetic, reacting to the magnet in the same way but to different degrees? And might not bismuth exhibit its peculiarities, not because it is in antithesis to iron, but merely because it is less magnetic than the air? Yet he writes as follows:

> "Such a view also would make mere space magnetic, and precisely to the same degree as air and gases Now though it may very well be, that space, air and gases, have the same general relation to magnetic force, it seems to me a great additional assumption to suppose that they are all absolutely magnetic, and in the midst of a series of bodies, rather than to suppose that they are in a normal or zero state. For the present, therefore, I incline to the former view, and consequently to the opinion that diamagnetics have a specific action antithetically distinct from ordinary magnetic action, and have thus presented us with a magnetic property new to our knowledge" ("Experimental Researches," Series XXI. No. 2440, Dec. 1845).

The extract describes his first-formed opinion.

PLÜCKER'S DISCOVERY OF MAGNE-CRYSTALLIC ACTION

The next important step is due to Plücker:

> In 1847, Plücker had a magnet constructed of the same size and power as that described by Faraday, his object being to investigate the influence of the fibrous constitution of plants upon their magnetic deportment; while conducting these experiments he was induced to try whether crystalline structure exercised an influence (Tyndall, "Diamagnetism and Magnecrystallic Action," p. 2).

The first experiment made by Plücker gave an immediate and decided reply. The investigation of the behavior of several crystals led him to announce the following laws:

> When any crystal whatever with an optic axis is brought between the poles of a magnet, the axis is repelled by each of the poles; and if the crystal possesses two axes, each of these is repelled with the same force by the two poles.
>
> The force which causes this repulsion is independent of the magnetism or diamagnetism of the mass of the crystal; it decreases with the distance more slowly than the magnetic influence exerted by the poles.

There is some truth in Plücker's conclusions, but much correction is necessary. Tyndall pointed out in 1850 that they broke down completely when applied to calcium and iron carbonate. These two crystals are isomorphous; the former, Iceland spar, obeys Plücker's laws in that it sets its axis equatorially in the magnetic field, but iron carbonate sets its axis from pole to pole. Plücker had, however, done great service in directing attention to the peculiar behavior of crystals in the magnetic field.

In the autumn of 1848 Plücker was in London. Faraday writes in his laboratory notes:

> 16 Aug. 1848. Plücker has described to me certain of his results as to the crystalline diamagnetic relation and, as I understand it, the optic axis of a crystal having *one* optic axis tends to pass into the equatorial direction, or if a crystal have two optic axes then the line between them tends to pass into the equatorial direction.
>
> 25 Aug. 1848. To-day Plücker showed me for the first time some of his experiments.

FIRST OPTICAL RESULTS

"A small rhomboid of Cal^c Spar was suspended by a single cocoon thread between my Elect. Magnet poles with the optic axis in a horizontal position. When the poles were very close as in the figure the diamagnetic force of the substance made it take the position shown in which the optic axis is axial to the magnet. But when the poles were opened out to distance of half or three quarters of an inch, then the mass pointed axially and the optic axis therefore equatorially. . . . There is a given distance between the Mag poles (pretty close) when a certain rhomboid $\overset{\text{or piece}}{\wedge}$ of Cal^c spar between them is so affected that the diamagnetic and the magneto-optic force is balanced, at smaller distances the piece points diamagnetic and at larger distances Magneto optic. So that on increasing the distance the magneto-optic force diminishes *less rapidly* than the magnetic force, and on diminishing the distance it increases less rapidly than the magnetic force. *But increasing or diminishing the strength of the magnet produces no alteration of this place of neutral action, it only increases or diminishes the strength of the action on each side of it: or rather the resultant of the two actions on each side of that neutral position.* So Plücker at least tells me, for I did not see that proved."

Plücker's experiment is readily shown; but a little care in adjustment is required. The dimensions of an equal-sided rhomb are rather too much the same in all directions: a somewhat more irregular piece is, I find, easier to work with. The effect is much more clearly seen with a good bismuth crystal, which was obtained in the following way. A little bismuth was melted in a glass tube which had been drawn to a point. The tube was placed in an electric furnace, from which it was made by clockwork to emerge very slowly. The fine end of the tube came out first, and the bismuth at the point was the first to solidify into crystalline form. The rest of the metal crystallized slowly as the emergence proceeded, and, in the circumstances, continued the structure and orientation of the first fragment. In this way, due to Bridgman, the mass contained large single crystals, not a mass of fine crystals as is usual when the solidification takes place rapidly.

When the crystal, which is ten times as long as it is broad, is placed in the magnetic field due to pointed poles, it sets strongly equatorially in accordance with the usual behavior of a diamagnetic body; but when the poles are withdrawn somewhat, it sets axially with equal strength.

The experiments of Plücker introduced a new effect which Faraday afterwards called "magne-crystallic action." It clearly deserves a name, since its manifestations added a complication to the diamagnetism which had already been observed.

The new discoveries presented so many forms when repeated with different crystals suspended in different ways and with different forms of magnetic field that the complications were not unravelled for some years. Some of the difficulties were due to the circumstances of the experiments and had no relation to the real question. One of these incidental effects was that of attractions and repulsions due to transient currents induced in bodies already suspended for observation between the magnetic poles when the magnets were excited. As is well known, the motion of a spinning block of copper is at once arrested by the action of such currents; on the other hand, a sheet of copper held near a pole is sharply repelled when the current is turned off, and if properly suspended can be set into a rapid spinning. These effects had nothing to do with diamagnetism, but they were apparently the cause of confusion on some occasions.

Another great source of difficulty was the overpowering effect of iron impurities; the diamagnetic effects are so feeble in all cases that a mere trace of iron, nickel or cobalt is sufficient to mask them. So, for example, Plücker's experiments with antimony seem on this account to have been at variance with the true facts as proved by Faraday (Tyndall, p. 16).

FARADAY'S RESEARCHES ON MAGNE-CRYSTALLIC ACTION

In 1848, Faraday published a series of researches on the magne-crystallic phenomena, which cleared up some of the difficulties. But in 1850 he could still write as follows:

> Four years ago I suggested that all the phenomena presented by diamagnetic bodies, when subjected to the forces in the magnetic field, might be accounted for by assuming that they then possessed a polarity, the same in kind as, but the reverse in direction of, that acquired by iron, nickel, and ordinary magnetic bodies under the same circumstances. This view was received so favorably by Plücker, Reich, and others, and above all by W. Weber, that I had great hopes it would be confirmed; and though certain experiments of my own did not increase that hope, still my desire and expectation were in that direction. (2641) Whether bismuth, copper, phosphorus, etc., when in the magnetic field are polar or not is, however, an exceedingly important question; and very essential and great differences in the mode of action of these bodies under the one view or the other must be conceived to exist. I found that in every endeavor to proceed by induction of experiment from that which is known in this department of science to the unknown, so much uncertainty, hesitation and discomfort arose from the unsettled state of my mind on this point that I determined if possible to arrive at some experimental proof either one way or the other. This was the more important because of the conclusion in the affirmative which Weber had come to in his very philosophical paper. . . . (2642) It appeared to me that many of the results which had been supposed to indicate a polar condition were only consequences of the law that diamagnetic bodies tend to go from stronger to weaker places of action; others, again, appeared to have their origin in induced currents.

Accordingly, he undertook a further series of researches which in the end brought him to regard all his effects as expressible in the simple form with which we are familiar. In his "Experimental Researches" he writes (Ser. XXVI, October, 1850, No. 2807):

> When a paramagnetic conductor, as for instance a sphere of oxygen, is introduced into such a magnetic field considered previously as free from matter, it will cause a concentration of the lines of force on and through it so that the space occupied by it transmits more magnetic power than before. If, on the other hand, a sphere of diamagnetic matter be placed in a similar field it will cause a divergence or opening out of the lines in the equatorial direction, and less magnetic power will be transmitted through the space it occupies than if it were away (see Fig. 1).

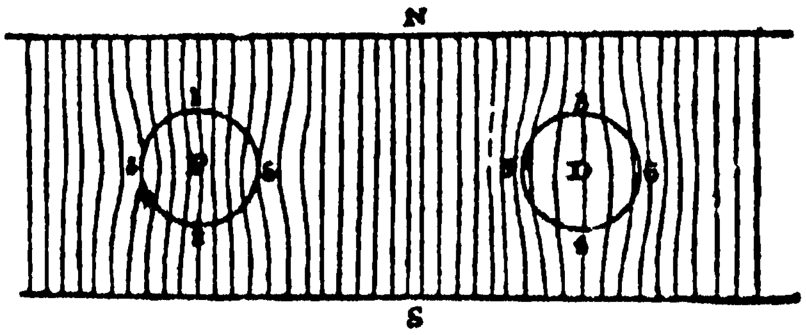

FIG. 1.—THE FIGURE IS TAKEN FROM FARADAY'S "EXPERIMENTAL RESEARCHES," AND WAS DRAWN TO SHOW HIS CONCEPTION OF THE PASSAGE OF LINES OF MAGNETIC FORCE THROUGH PARAMAGNETIC AND DIAMAGNETIC BODIES RESPECTIVELY.

This describes diamagnetism generally: the complication of magne-crystallic action is described with equal simplicity:

> (2837) If the idea of conduction be applied to these magne-crystallic bodies it would seem to satisfy all that requires explanation in their special results. A magne-crystallic substance would then be one which in the crystallized state could conduct onwards, or permit the exertion of the magnetic force with more facility in one direction than another: and that direction would be the magne-crystallic axis. Hence, when in the magnetic field, the magne-crystallic axis would be urged into a position coincident with the magnetic axis by a force correspondent to that difference, just as if two bodies were taken, when the one with the greater conducting power displaces that which is weaker.

It is only a uniaxial crystal, of course, which possesses a single magne-crystallic axis; it is the axis of a certain spheroid. The facility of conduction in different directions in a biaxial crystal requires an ellipsoid for its representation.

This way of stating the rules allows us to see at once the principle of the experiments shown by Plücker to Faraday, which the latter so greatly extended. When the magnet poles were close, the crystal occupied a part of the field where the lines of force were very divergent. In such circumstances the orientation of the crystal would be determined by the general tendency for diamagnetic bodies to move from the stronger to the weaker parts of the field, and the crystal set its longer dimension perpendicular to the field; the optic axis was then parallel to the lines of force. But when the magnetic poles were separated the crystal covered a part of the field in which there was little divergence: the magne-crystallic action then took charge, and the crystal set itself so that the direction of worst conduction of the lines, *i.e.*, the optic axis, was at right angles to the lines.

EXPERIMENTAL ILLUSTRATION OF MAGNE-CRYSTALLIC ACTION

A few simple experiments will serve as further illustration of these rules. We take a crystal of sulphate of iron which has the form of a thin plate: the flat sides are cleavage planes and the "conducting power" for Faraday's lines is far greater across the plate than along the large faces. In a uniform field the crystal plate sets equatorially therefore, and even when allowed to move up to one of the poles keeps its face normal to the lines. A thin plate of iron would stand on edge on the pole: but the magne-crystallic action of this paramagnetic crystal is exceedingly strong.

A bismuth crystal so suspended that its axis (it is a uniaxial crystal) is vertical has no magne-crystallic action. Its motions are governed by the general tendency of its mass to move from the stronger to the weaker parts of the field: in a uniform field it has no appreciable tendency to set itself in any particular direction. But when the crystal is hung so that the axis is horizontal, that axis tends strongly to set itself along the lines of force, as we saw before.

Naphthalene is a monoclinic crystal. Its magne-crystallic properties are represented by an ellipsoid, one axis of which coincides with the single axis of symmetry. The cleavage is very perfect and the crystals take the form of thin plates parallel to the cleavage planes. The axis is also parallel to the cleavage planes, and if the crystal is suspended so that this axis is horizontal and the cleavage planes vertical, the axis and the planes move into the equatorial position, in this way fulfilling symmetrical considerations. But when the crystal is hung in a uniform field, so that the axis is vertical, the cleavage planes set themselves at a certain angle to the field. One of the axes of the magnetic ellipsoid then lies along the lines, another across them: the third is vertical. There is no obvious relation between the cleavage plane and the first two axes. Finke (*Annalen der Physik* **31**: 149: 1910) has shown that this may be said of various crystals examined by him. If now the crystal be suspended from the other end of the axis, its cleavage planes will make the same angle with the field but on the opposite side of the medial line (Fig. 2). Faraday describes results of this kind which he obtained with a paramagnetic crystal of sulphate of iron ("Experimental Researches," Series XXI, Nos. 2634–7). Naphthalene is diamagnetic: like many other organic crystals, it shows the magne-crystallic effect very strongly.

These experiments will serve to show the great variety of effects that may be observed. All of them are, however, easily correlated by Faraday's concep-

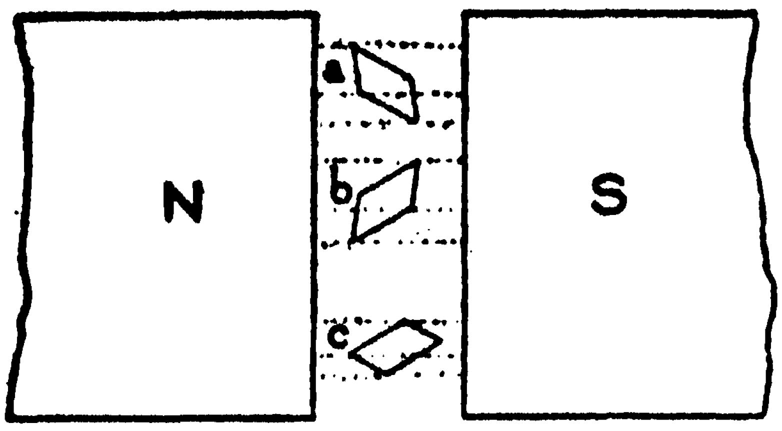

FIG. 2.—In this figure the positions marked *a* and *b* are positions of equilibrium of the naphthalene crystal in the magnetic field. The axis of symmetry is vertical and perpendicular to the plane of the paper. The cleavage plane is also vertical and its intersection with the plane of the paper is the longer side of the rhomboid. The form of the crystal shown in the figure is not a natural form, because the shorter side of the rhomboid is drawn parallel to one face of the cell of the crystal lattice, which face does not usually occur on the crystal. It is so drawn in order to show the relation between magnetic lines and the lattice. If the crystal is hung from one end of the *b* axis, the position *a* is assumed, and if from the other, the position *b*. The position *c* is impossible.

tion of lines of force. Let us remember that there are several variables and give due importance to each. The first of these we call diamagnetism, implying that the lines pass through the substance in question less easily than through the air or a vacuum. The second is called magne-crystallic action, in reference to the fact that in a crystal the lines pass more easily in one direction than another. A third variable is the crystal shape, which may also affect the set in the magnetic field when the latter is divergent. A fourth is the amount of divergence of the field which, in a uniform field, falls to zero. After experimental disturbances have been allowed for, all these influences have to be taken into account.

The more divergent the field the more does the simple diamagnetic effect assert itself, and any magne-crystallic action which would tend to make the specimen set a crystal axis or axes at some particular inclination to the direction of the field is overpowered.

THE CONTRAST BETWEEN PARAMAGNETISM AND DIAMAGNETISM

On the other hand, magne-crystallic action usually takes charge in a truly uniform field. For the sake of brevity and an easier explanation, it may be well to direct attention to a fact which was not fully appreciated by all the first experimenters, but was clearly set out by Sir William Thomson (Lord Kelvin) in 1885. A diamagnetic bar, apart from magne-crystallic action, tends to set itself *along* the lines of force in a *uniform* field, just as a paramagnetic bar. For we may imagine the bar to be made up gradually of a collection of cubes, placed successively one after the other in the magnetic field. The effect of the first cube is, as we should say in the language of Faraday, to spread out the lines of force on their way through the cube, and to crowd them together on either side of it. A second diamagnetic cube will, if free to move, go to that part of the field where the lines are least crowded; it will therefore avoid setting itself beside the first cube and prefer to place itself in front or behind it. A third will continue the same process, and in the end the cubes will form a bar pointing along the lines. In the case of a substance such as iron, there is a double converse. The lines are most dense just in front and just behind the first cube; and a second cube will place itself in one of those positions because a magnetic substance seeks the strongest part of the field. Again, therefore, the bar grows along the lines, as in this case we know from experience (see Fig. 3).

It is quite certain that no one has ever seen the first of these effects, because it must be so minute and difficult to separate from others. We may safely infer it, as Thomson pointed out, because our theories of the electromagnetic field have been abundantly justified by other means. The susceptibility of bismuth, by far the most diamagnetic substance, is

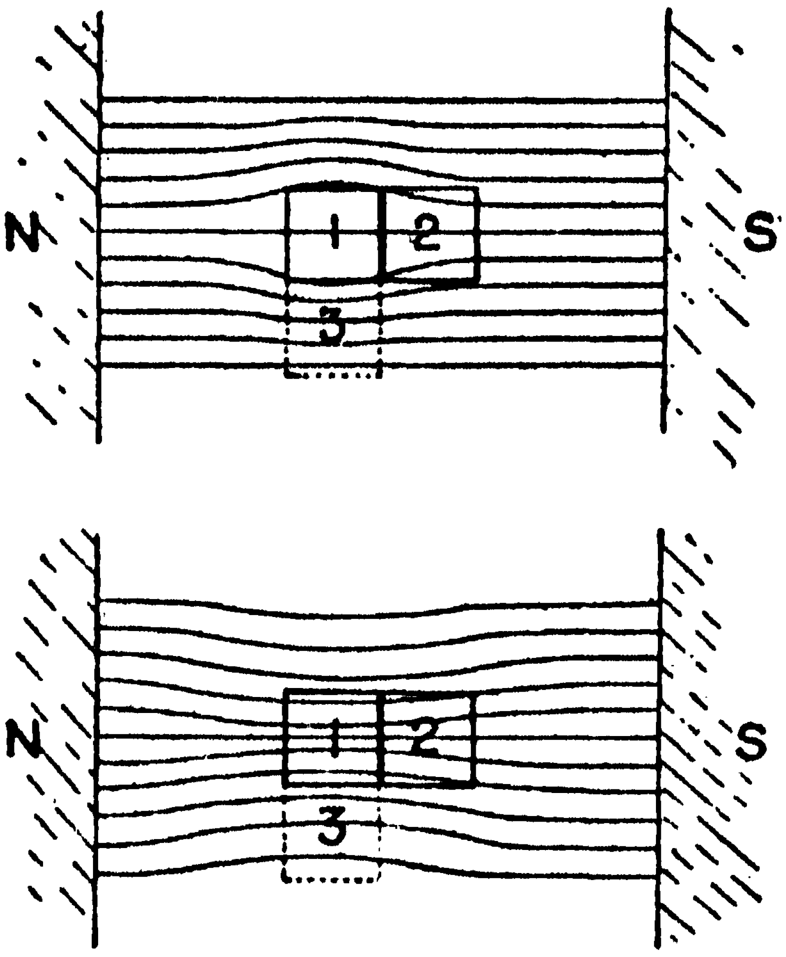

FIG. 3.—DIA- AND PARAMAGNETIC SUBSTANCES IN A MAGNETIC FIELD. IN BOTH CASES POSITION 2 IS PREFERRED TO POSITION 3.

only about 10^{-6}; in other words, the strength of the field on one side of a bismuth cube of 1 cm side would only be about a thousandth part of 1 per cent. greater than at the front or back of the cube. Near a pointed pole the strength of the field might easily vary by 50 per cent. in a centimeter. It is easy to see how feeble is the force tending to arrange the supposed cubes parallel to the lines of a uniform field as compared with the forces acting on a bar placed near the pole.

The analogous effect in electrostatics can, however, be realized. When two plates are immersed in oil and maintained at a large difference of potential, an elongated rod of glass hung from a fiber sets itself along the lines of force (to make sure that the effect is true the rod must be free from any conductivity due to its own substance or a water film). This corresponds to the setting of a magnetic body in a uniform field. When bubbles of air are allowed to rise through the oil they are[3] drawn out along the lines of force; which effect, since the inductivity of air is less than that of oil, represents the setting of a diamagnetic body along lines of magnetic force.

When a diamagnetic substance sets itself across the lines of a magnetic field, and no magne-crystallic action is at work, it is because the field is not really uniform. It is perhaps a little confusing when it is said, as is sometimes the case, that diamagnetic and paramagnetic substances are the antithesis of one another in that one kind sets itself across the field and the other along it. This is only true of a field which is non-uniform. Indeed, it may be said that the use of the word antithesis is incorrect in any case. There would be a true antithesis if one substance could be defined by its pointing along the lines of force in one direction while another pointed in exactly the opposite direction; there is no true antithesis between pointing along the lines and pointing across them. It seems to me, though I say it with diffidence, that this difficulty was stirring in Faraday's mind and was the true cause of the uneasiness of which he spoke in a quotation given above, and of his aversion to the description of diamagnetism and paramagnetism as being the antithesis of one another.

Faraday, as I have said, when this thorough examination of the facts had led him to frame a hypothesis which would link them together, based his interpretation on the existence of lines of force, and found himself able to place both his own results and those of others in their place within a self-contained system.

Kelvin placed this hypothesis in mathematical form, thus completing the treatment of the subject of magnetism by Poisson; the latter had left out of his consideration the consequence of magnetic susceptibility being different in different directions, not because he overlooked the possibility of such an effect, but because no case of its occurrence was known to him.

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[3] My authority is Capt. Dunsheath of the Henley Telegraph Works Co.

THE HYPOTHESIS OF POLARITY

Faraday's views were not accepted, however, by other experimenters on the same subject, and in particular by Tyndall. The idea of polarity was not to be given up easily, and innumerable experiments were made to show that a "diamagnet" had poles like a magnet, but in the opposite sense. A bar of bismuth would develop north and south poles when, in similar circumstances, a bar of iron would develop south and north. Of course, when the facts are prepared for mathematical treatment, they can be expressed in this way. It is generally convenient and justifiable to represent a magnet by two poles because the form of the field at any reasonable distance is satisfactorily represented thereby, though in the immediate neighborhood the lines of a real magnet do not run like those of the theoretical bipole. Within the body of the magnet the lines run from the south pole to the north, continuing and completing their course outside so that every line is a closed circuit; but all lines near a bipole run from the north pole to the south pole. So also in the magnetic shell, which is in the mathematical treatment the exact analogue of the electrical condenser, the bulk of the lines run from one plate to the other across the narrow space between the two plates; comparatively few run from the outside of one plate, through surrounding space, to the back of the other. In the condenser, the internal field is the most important, the external being looked on as a correction. In the magnetic shell the reverse is the case; the outside field is that which is considered because it represents more and more closely, as the plates are brought closer together, the field due to a current circulating about the contour of the condenser. The theoretical charges on the plates have to be made larger and larger as the plates are brought together, so that the strength of the outside field may remain the same.

Now, if a piece of bismuth is placed along the lines of a magnetic field, the lines avoid the piece to some extent, though, as already explained, the avoidance is extremely small. If we take the bismuth away and replace it by a feeble bipole consisting of south-pole magnetism, of proper amount, where the lines come out of the bismuth, and a corresponding amount of north-pole magnetism where they go in, the whole arrangement being made in a vacuum, or permissibly, in the air, we get (Fig. 4) in this artificial way an external field resembling that which exists when the bismuth is in place. It can be said that polarity is developed in the bismuth in a sense opposite to that which is found in iron in the same circumstances. If the effect is to be represented, for the convenience of treatment, as due to the presence of a bipole, then the sense of the bipole in the case of bismuth is opposite to the sense in the case of iron. The old argument, therefore, was not between two hypotheses but between two languages in terms of which the facts were to be described. Such an antagonism, once believed in and debated, could be and was the cause of an immense variety of experiments devised to justify one side or the other. But Faraday felt that his way of putting the facts was more fruitful in suggestion of further experi-

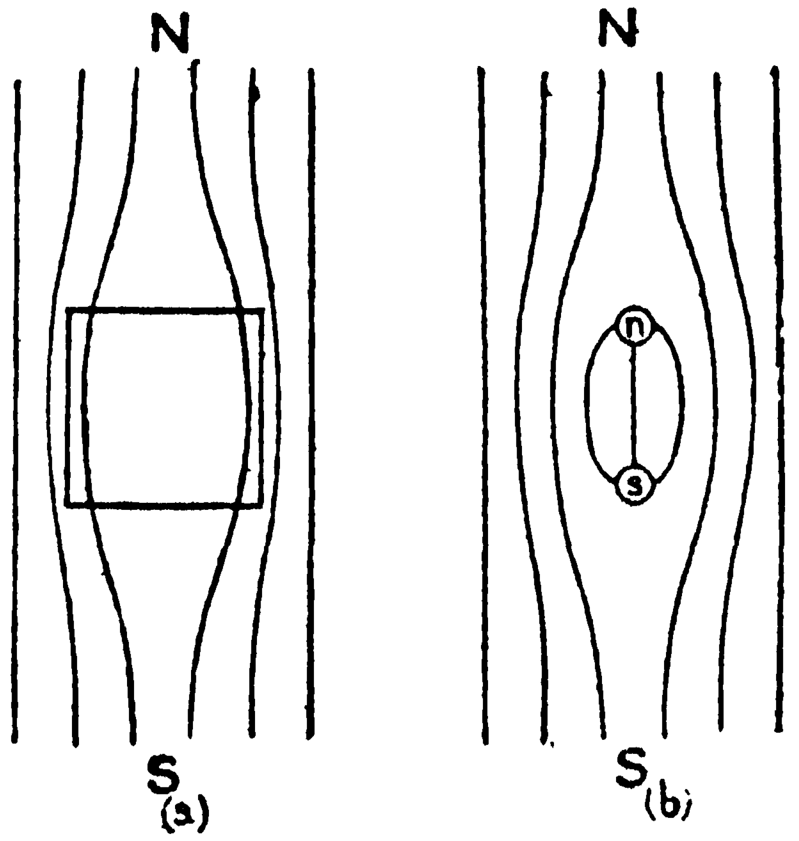

FIG. 4

ments, and more convenient as a foundation for theoretical development. He has been abundantly justified.

THE WORK OF TYNDALL AND KNOBLAUCH

We now come to the part which Tyndall played in a debate which was conducted on both sides in such an able and, it is pleasant to observe, in such a friendly way. In the first place, Tyndall and Knoblauch published in 1850 an account of experiments which they had made. They showed that Plücker's first views, those which included the repulsion of the optic axis of a uniaxial crystal by the poles of the magnet, were, as already stated, incorrect in many cases, and they substituted an amended set of rules in the following terms:

> If the arrangement of the component molecules of any crystal be such as to present different degrees of proximity in different directions, then the line of closest proximity, other circumstances being equal, will be that chosen by the respective forces for the exhibition of their energy. If the mass be magnetic this line will set axial; if diamagnetic, equatorial.

The key-word is "proximity." This condensed statement of course requires explanation. Tyndall supplies it in full in his book on "Diamagnetism and Magne-crystalline Action." A very brief summary will be sufficient for our present purpose. In the first place, the observations made by him and his partner on the behavior of crystals in the magnetic field convinced them that the plane of cleavage determined in a number of cases the position which the suspended crystal would take. Magnesium sulphate, zinc sulphate, saltpetre, and topaz were diamagnetic substances, and their cleavage planes, the crystals being so suspended that these planes were vertical, always set themselves equatorially, *i.e.*, at right angles to the field. On the other hand, nickel sulphate, scapolite and beryl, which were magnetic crystals, in the same circumstances set their cleavage planes parallel to the field.

The connection between these results and the statement quoted above lies in this, that the molecules in a crystal were supposed to be in greater proximity along a cleavage plane than in any other direction. Let us take bismuth as an example; it is diamagnetic and sets its cleavage plane equatorially in accordance with Tyndall's rule. Its structure has now been determined by X-ray analysis, so that we can see what meaning can be attached to the claim for proximity in the plane of cleavage. The bismuth structure can be looked on, approximately, as a slightly distorted cube; one of the cube's diagonals has been a little stretched, while the other three have been left unchanged. The crystal is therefore uniaxial; the axis is the stretched diagonal. The principal cleavage plane is perpendicular to the axis. The spacing of the planes parallel to the cleavage is larger than that of any other set of planes in the crystal, and these consequently contain more molecules to the unit area than any other planes. Tyndall would have said that in those planes there was a maximum proximity between the molecules.

The X-ray analysis of other crystals often shows the cleavage plane to have the largest spacing and therefore the closest degree of packing. This means that the points of the crystal lattice are closest together in that plane, but it does not mean that the atoms or molecules are nearer together in that plane than in any other. Nothing can be said about that until the actual distribution of the atoms in the unit cell has been determined. It would be much safer to say that the existence of a cleavage plane implies a certain *looseness of packing* across the crystal planes which are parallel to the cleavage. This would imply a greater tightness in other directions, but not necessarily a greater proximity. It is only at first glance that the latter term seems to have a clear meaning. But we must let it stand in order to realize the argument as it presented itself to the authors of the statement quoted.

It happens that in the case of bismuth we do actually find a closer bonding between the atoms in the cleavage plane than in any other; but this is peculiar to the structure of bismuth and has no relation to the supposed close proximity of *molecules* in the cleavage plane.

Now we come to the essential point of the argument. It is supposed that proximity offers magnetism or diamagnetism, whichever it may be, the opportunity to "exhibit its greatest energy." We are to remember that the hypothesis on which we are working expresses itself in terms of poles and that a magnet attracts a piece of iron by inducing poles in it, which poles then react with the poles of the magnet. When a piece of iron is allowed to attach itself to a magnet, the poles induced in it are much stronger than if the magnet and the iron are separated by a little distance. If a second piece of iron is brought near the first, every increase in its proximity increases the strength of the poles which are developed in this piece by the influence both of the original magnet and of the first piece of iron.

A simple experiment will serve as an illustration (Fig. 5): The nail hangs in the first case, and not in the second because the close proximity of the iron blocks increases the strength of the poles in all of them. In the second case, the nail will not hang, although the magnet is actually closer to it. The benefit of mutual "proximity" of the separate pieces of iron is obvious. An equally simple explanation can be given in terms of lines of force, but we are using the alternative language.

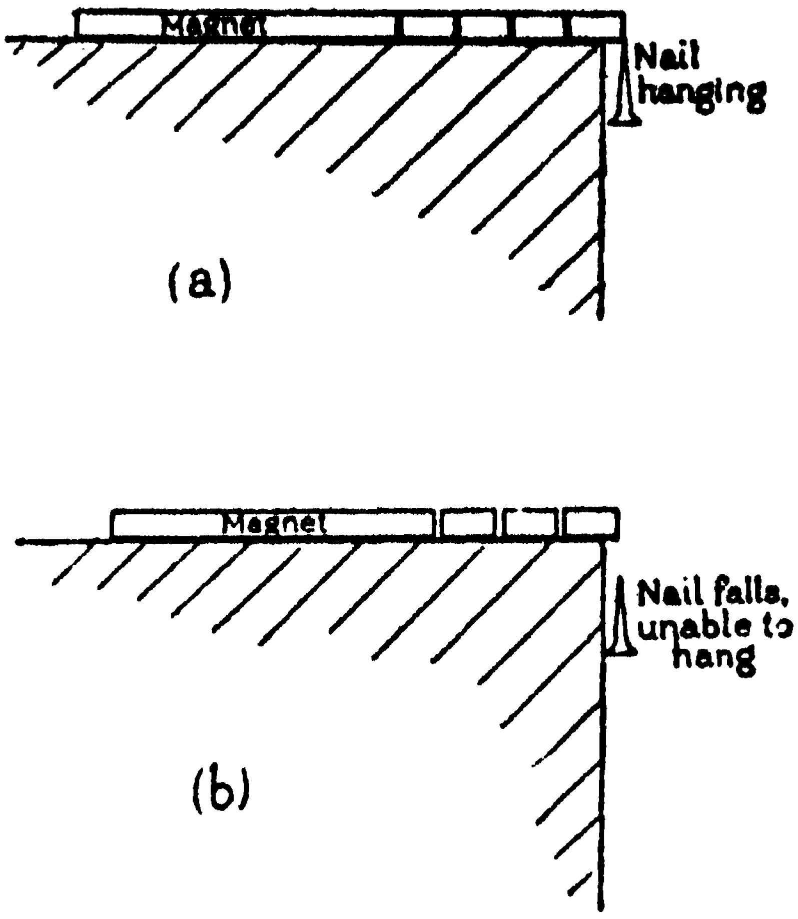

Fig. 5.—When pieces of iron are all in contact with one another and the end one with the magnet, the nail can hang as shown in (*a*). But when, as in (*b*), the iron blocks are somewhat separated from one another and from the magnet, the nail falls.

Chains of iron fragments form readily between magnet poles of opposite nature. A rod of iron "transmits the magnetic force," and generally acts more efficiently than a set of iron fragments which are not allowed to get into close proximity with each other. Tyndall sticks short lengths of iron wire through disc-shaped pieces of apple and shows that the disc sets itself at right angles to the field, the bits of wire therefore lying parallel thereto. In each bit are many molecules of iron in close proximity, and the fact is more effective in directing the apple than the existence of a number of bits scattered over the disc without being in "proximity" to each other.

Diamagnetism and "Proximity"

It is now argued by Tyndall that if the magnetic influence of a magnet is extended by means of proximity, the diamagnetic influence must be extended in the same way. If the close proximity of iron fragments will help them to set with greater firmness in the direction joining opposite poles, then the closer proximity of bismuth fragments should cause them to set with greater firmness across them. In this way Tyndall interpreted the rule, which he believed he had established, that the cleavage planes of magnetic crystals tended to set axially, and those of diamagnetic crystals equatorially.

It is interesting to observe that Tyndall was attempting to supply both a rule for the setting of crystals and an explanation of the rule in terms of structure. Faraday stopped short when he had supplied a picture of the distribution of his magnetic lines, or, as we should now say, a map of the distribution of energy in the magnetic field.

As I have already pointed out, there is no clear meaning to the term "greater proximity in the cleavage plane." Moreover, if conclusions were to be drawn from analogy with phenomena on a larger scale, they would run contrary to the intended argument; for, on that scale at least, a line of diamagnetic masses tends to set itself axially, not equatorially. A piece of bismuth makes an extremely minute alteration in the disposition of the lines of force, for which reason it is a very poor detector of the existence of the lines in comparison with iron; and the change, since it is so small, can indeed be detected by a piece of iron in the form of a magnet, but certainly not by another piece of bismuth, no matter how close they are together.

In the case of a uniaxial crystal, a principal cleavage must from symmetry considerations be related to the axis and, if it is unique, must be perpendicular thereto. When there is more than one cleavage, the cleavage planes must be symmetrically disposed about the axis as in the case of Iceland spar. It is not, therefore, surprising that, in the former case, the cleavage plane should place itself exactly, either equatorially or axially, and that in the latter case a plane perpendicular to the axis might be looked on as a resultant of cleavage planes and therefore set itself equatorially. But it does seem remarkable that, as Tyndall pointed out, the substitution of iron for calcium in Iceland spar, to form the isomorphous iron carbonate, should turn the structure round through 90° in the magnetic field; especially if we assign diamagnetism and paramagnetism to different causes. It may be there are other cases of the same change; and any rule of this kind must clearly be of importance.

THE EFFECTS OF PRESSURE ON MAGNETIC SUSCEPTIBILITY

We now come to another set of experiments, very interesting and important, which were used by Tyndall in the defense of the "polarity" position. The method of these experiments was suggested by an accident. When working in Berlin with a fine magnet placed at his disposal by Magnus, he was observing the action of the magnet on a bismuth cube which was so shaped that two opposite faces were perpendicular to the optic axis and parallel to cleavage planes. When the current was switched on, the magnet poles rushed together because the separate parts of the magnet had not been properly bolted down. The bismuth cube was crushed to some extent. Working conditions having been restored, it was found that the bismuth set itself at right angles to its former position. The line of pressure, which, of course, had been parallel to the field, was now perpendicular to it. Tyndall now argued that the particles of bismuth had been brought into greater proximity by the pressure and that the setting of this line of great proximity was in accordance with the rule given by himself and Knoblauch. So began an extended series of researches on the effects of pressure which are fully described in his book. As an example let us take the following:

> A quantity of bismuth was ground to dust in an agate mortar, gum-water was added, and the mass was kneaded to a stiff paste. This was placed between two glasses and pressed together; from the mass when dried two cubes were taken, the line of compression being perpendicular to two of the faces of each cube and parallel to the other four. Suspended by a silk fiber in the magnetic field, upon closing the circuit the line of compression turned strongly into the equatorial position. . . .

When carbonate of iron was used the line of pressure set axially.

Such an experiment is very striking,

whatever its explanation may be. Tyndall argued that he had by compression increased the proximity along the line of pressure, but it is difficult to see how this can be. If a number of particles of one kind are distributed with complete irregularity in a paste medium which is then subjected to pressure in one direction, the alteration in form of the paste block will not alter the law of distribution of the particles. In any case, as we have already seen, proximity does not produce any observable effects.

LORD KELVIN'S EXPLANATION OF TYNDALL'S RESULTS

It is surely natural to suggest that the particles acquired some orientation from the pressure, which might well happen if they possessed shapes which were related in some particular way to their structures. Thomson immediately pointed this out to Tyndall, who replied that if that were the case, the bismuth fragments being naturally in the form of flakes parallel to the cleavage plane, the line of pressure ought therefore to set itself axially, whereas it actually set equatorially. This was certainly a good reply. Perhaps the counter argument is that the crystal fragments have not actually been shown to set in this way. Miss Knaggs has made an X-ray measurement of the set of the fragments in one specimen of squeezed dough containing bismuth particles, and has found that the cleavage planes are not closely coplanar with the surface, as they must be if Tyndall's argument is to be good. Though this is a single example, it looks as if a way of escaping the difficulty was to be found.

As I have said, Tyndall's reply to Thomson was good, but, to use his own words, though it formed "a strong presumptive argument it was not yet convincing." He strengthened his case greatly by a further experiment. Comparing the repulsion exerted by a magnet on a natural crystal of bismuth with that exerted on a mass of compressed powder in dough, he found the latter greater than the former. He had cut the crystal into the form of a cube and placed it on one arm of a torsion balance so that the cleavage plane was perpendicular to the magnetic field, and the repulsive force as great as it could possibly be. The dough had been pressed into a cube of the same size and placed with its line of pressure at right angles to the field. Tyndall argued that there must be a direct effect of pressure, since it had done more than all that the natural phenomena could do.

Now it is clear that if the orientation of a bismuth crystal in a uniform magnetic field, *i.e.*, the magne-crystallic action, is due to the arrangement of the atoms and molecules in the crystal structure, the perfect crystal ought to show the effect more perfectly than the fragments distributed through the dough, however perfectly the latter may be arranged. But Miss Knaggs has made an X-ray photograph from the face of a natural "crystal." The specimen was chipped out of a mass of crystals left in a crucible, and must have resembled that which Tyndall used. The photograph showed at once that the specimen was a compound of more than one crystal, and that different orientations were present. Cleavage planes, and also others which in a single crystal would make large angles with the cleavage planes, were nearly parallel to the face under test. It is possible, therefore, that there was really more of the effective orientation in the pressed specimen than in the natural piece. A photograph of the single crystal made by Bridgman's method taken in the region of the cleavage plane gave a much cleaner picture.

A piece of bismuth can be looked on as an aggregate of crystals. There may be but one perfect crystal or there may be a number, small or large, of smaller crystals, each perfect. If proximity were increased by pressure, the change in proximity would have to occur in respect to the mutual distances in either of the separate crystals, or of the atoms and molecules in the single crystal. The X-ray analysis shows that the latter alternative is impossible, because from many tests recently carried out in respect to metal structure, we learn that no permanent change in the crystalline lattice is occasioned by stress. The former alternative is also ruled out, because, as Faraday pointed out,[4] bismuth is actually of a lower density after compression than it was before; the pressure having of course been removed. Apparently the breaking up of the specimen increases the extent of the cavities.

Tyndall made many paste models of crystals, mixing powders of bismuth, carbonate of iron, or other active substances with flour and water, or gum. He pressed the mass by different amounts in different directions and then cut it to shape; in this way he imitated the magne-crystallic action in detail. At one time, in order to meet the objection that he was merely rearranging the small crystals in his paste and conglomerates, he took some white wax "concerning whose amorphism there can be but little doubt." The substance is diamagnetic. A little cylinder of the wax suspended in the magnetic field set with its axis equatorial. It was then placed between two stout pieces of glass and squeezed as thin as a sixpence; suspended from its edge, the plate thus formed set so that its length, which coincided with the axis of the previous cylinder, was axial and its shortest dimension equatorial. But we know now that wax is anything but amorphous; its crystalline structure has not only been observed but also accurately measured; and we know also that pressure arranges the orientation of the crystals.

Tyndall obtained the same result with a piece of bread, and we may repeat the experiment. A small piece of the crumb is squeezed between two glass plates, and the edges of the irregular mass are trimmed off, so as to leave a thin disc. When this is suspended so that its plane is vertical, it sets equatorially if the poles are close together and the field is very divergent. It is therefore diamagnetic. But when the bread is moved from the space between the poles to a more uniform part of the field, the plane of the disc turns through a right angle and sets itself parallel to the lines of force. It is quaint to observe how the bread, as it is moved up to the poles, sets itself to pass neatly through the narrow gate and take up a parallel position on the further side. This is due to magne-crystallic action, so that the bread contains crystals, a fact easily verified by X-ray methods.

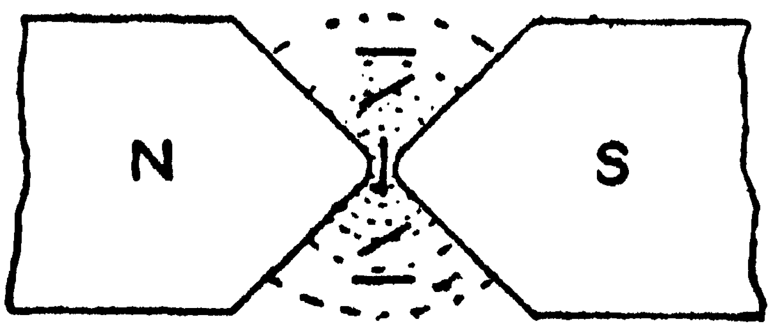

FIG. 6.—THE BLACK LINES SHOW DIFFERENT POSITIONS OF A THIN WAFER OF PRESSED BREAD HUNG BY A SINGLE FIBER. IN THE OUTER PARTS OF THE MAGNETIC FIELD IT SETS MORE OR LESS ALONG THE LINES, BUT AS IT IS BROUGHT UP TO THE MORE INTENSE PARTS, WHERE THERE IS GREAT DIVERGENCE OF THE LINES, IT TURNS SO AS TO SET ITSELF AT RIGHT ANGLES TO THE FIELD.

THE EFFECTS OF PRESSURE ON CRYSTALLINE CONDITION

The long series of interesting and ingenious experiments which Tyndall made to show that pressure produced proximity and proximity produced the equivalent of magne-crystallic action, must be held to have failed in their original purpose. But they will doubtless be put to a different use. They are related to a subject of immense importance in these days, namely, the effects of pressure and tension and mechanical treatment generally, upon the state of a material and upon its physical properties. The consideration of such questions is fundamental to metallurgy and to other industries. The microscope has for many years been employed for the purpose, and the new methods of X-ray analysis are already being put into service. It may well repay us to consider Tyndall's experiments in a new light; and to examine the actual nature of those rearrangements which produced such remarkable changes in magnetic reactions. Tyndall himself discussed the effects of pressure in producing planes of possible cleavage, and was one of the pioneers in showing how such planes, occurring in the earth's crust, were not always to be interpreted as the result of sedimentary deposition, but rather of pressure, which might, if it were exerted more or less along the deposition planes, produce cleavages across the latter. He extended the principle to account for stratification in rolled materials, even in biscuits and pastry!

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[4] His reference was to "Gmelin's Handbook of Inorganic Chemistry," vol. 4, p. 428.

Faraday's use of lines of force did not, in reality, demand so much framing of hypothesis as Tyndall's polarity. It is to be observed that, as Faraday pointed out, they had no differences about facts, merely about methods of description, which methods, however, were of different value as suggesting development. To Faraday's conceptions have been added theories of magnetism and diamagnetism based on the existence of resistanceless molecular circuits as imagined by Ampère and Weber, or on revolving electrons as explained by Langevin. In the most recent times the quantum theories have again modified our ideas.

MODERN CONSIDERATIONS

The crude hypothesis of the molecular circuit leads simply to a useful point of view of the difference between paramagnetism and diamagnetism, and the most modern discussions, though they differ greatly in appearance, leave that point of view almost untouched. If any of Faraday's lines of force thread a circuit which has no electrical resistance, that number can never be changed. If, therefore, a substance be brought into a magnetic field, the molecular circuits in the atoms of the substance act like obstructions to the lines; and the total obstruction, of which the negative magnetic susceptibility is a measure, is proportional to the sum of the areas of all these circuits, as projected on a plane perpendicular to the lines. It is of no consequence whatever whether there are already currents in those circuits; unless, indeed, the circuits are movable and can alter their set towards the imposed field. Thus the diamagnetism is unaffected by the existence of molecular magnetic fields; or by any changes in them, so long as the total of the projected areas of the circuits is unchanged.

This result does not hold if circuits approach each other so closely that they offer less obstruction to the lines than if they were more separated. Two resistancesless circuits running closely parallel to each other offer little more opposition to the passage of lines than either circuit alone. We should imagine that such changes in the relative position of circuits would only occur in strenuous circumstances such as, possibly, those of crystallization. It is known that diamagnetic susceptibility may vary very slightly: for example, Oxley has shown that crystallization sometimes brings about small but definite alterations. As has often been pointed out, this simple theory makes diamagnetism a property of all substances, which can be affected, even overwhelmed, when the circuits already contain currents, and therefore can be orientated afresh by the magnetic field.

Let me say in conclusion that although recently acquired knowledge of the structure of materials leads us to reconsider Tyndall's experimental results, we are still far from the full explanation of the connection between structure and magnetism, and of the influence of the latter upon physical properties.

THE DEATH PENALTY FROM A SCIENTIFIC POINT OF VIEW

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Apparently, the death penalty originated in this way: A long time ago, before the processes of common law had taken form, when a man was murdered, his relatives were given the privilege of revenge. They were allowed to administer their own justice; and they went out and got some one. But the doubt as to whether they always got the right one was too great. So the law removed this privilege of private killing—together with the burdens and risks that must have accompanied it if the other parties happened to be strong—and undertook to administer its own justice. And, little by little, arising thus from sources that pass back of the memory of man, the common law has built up a judicial process leading to the death penalty, which now entirely eliminates the idea of revenge, substituting for it the repression of crime, and which attempts to establish the maximum degree of certainty as to the guilt or culpability of the one who is accused. The methods for establishing this maximum degree of certainty, having likewise gone through several modifications, are now reduced to one basic principle, which is that the judgment of the case shall be free from reasonable doubt. So the death penalty depends upon the interpretation of *reasonable doubt*: What is the degree of confidence in a judgment that puts it beyond reasonable doubt?

This was the situation in the law, we may say, a hundred years ago. But more recently there has been arising a feeling, both within the law and elsewhere, that a degree of certainty that is beyond reasonable doubt is, perhaps, not so readily attainable as it appeared to be a hundred years ago. The standards of reasonable doubt have varied in the law from time to time; the judges have not always agreed about them. Moreover, the problem of the degree of certainty of a result has become, in the scientific field, one of the branches of learning, with standards now generally accepted that differ from those of the law, and with text-books discussing them. The degree of certainty of a result, or the confidence that may be placed in it, or its freedom from reasonable doubt, are merely different ways of expressing one and the same idea, the probability as to its accuracy, whether the result in question is a measurement, or an hypothesis or a principle or a judgment—they all exist in the scientific field quite as much as in the legal field. So it may be of interest to compare the legal and scientific methods and to observe how the law would be affected if the scientific methods and scientific conceptions were to be used in it. In a word, this effect would be that, by scientific interpretations, the legal methods do not reach a degree of certainty that is free from reasonable doubt.

The difficulties that exist in the legal methods for determining reasonable doubt may be seen from the citations that follow:

> It is difficult to conceive what amount of conviction would leave the mind of a juror free from a reasonable doubt, if it be not one which is so settled and fixed as to control his actions in the more weighty and important matters relating to his own affairs. Out of the domain of the exact sciences and actual observations

> there is no absolute certainty. The guilt of the accused, in the majority of criminal cases, must necessarily be deduced from a variety of circumstances leading to proof of the fact. Persons of speculative minds may in almost every such case suggest possibilities of the truth being different from that established by the most convincing proof. The jurors are not to be led away by speculative notions as to such possibilities. (120 U. S. 439.)

But the judges have felt, from time to time, in order to aid the juries, that they must give the term reasonable doubt a more definite meaning; as, for example, that a reasonable doubt is the antithesis of an abiding conviction—

> . . . where there is an abiding conviction of the truth of the charge resting in the minds of the jury, there can not be at the same time, in the same mind, a reasonable doubt. (122 Ill. 8, 251.)

Such a definition was based originally upon a judge's view of the fundamental conceptions of law (5 Cush. Mass. 320). Thereafter, it was cited by other judges as the law; the legal substitute for reasonable doubt; that which determined it, and played its part in the destiny of many lives, sometimes for freedom and sometimes not. Then it fell into disuse because it no longer conformed to the conceptions of the judges. Now the tenor of the decisions seems to be that reasonable doubt needs no further definition (156 U. S. 185, 199; 218 U. S. 245). Other definitions followed a similar course; such as, *proof to a moral certainty, cause to hesitate and pause.*

These definitions have been severely criticized in the decisions themselves. "The words 'to a reasonable and moral certainty' add nothing to 'beyond a reasonable doubt' " (120 U. S. 430, 439). "Each has been used by eminent judges to explain the other" (118 Mass. 1, 24), "They are ill-advised efforts" (4 Wigmore, Evidence, Sec. 2497). And,

> . . . it has been uniformly held that a reasonable doubt is one . . . such as, in the graver transactions of life, would cause a reasonable and prudent man to hesitate and pause. . . . The instruction [the abiding conviction definition] . . . in a case where the testimony is conflicting, or such as to leave the minds of the jury in doubt, [it] would be likely to prejudice the jury . . . we do not hesitate to condemn the instruction. (109 Ill. 636.)

Other definitions seem to depend upon these, involving the same difficulties.

Contrasted with these legal conceptions, the scientists have built up standards of certainty by which they determine the confidence that may be placed in a result, that is, its freedom from reasonable doubt; and these scientific standards now constitute a subject that is known as precision of measurements. Perhaps the alternate legal phrase, the reasonable certainty of a result, fits the scientific conceptions more directly; for the scientist determines what the degree of certainty of a result may be; and from this he establishes the conditions that will give the utmost degree of certainty attainable at any given time.

Scientific conceptions, in the first place, are never free from an underlying probability—it is even itself a feeling of certainty—that all its judgments will be modified at some time in the future. About all its judgments of the past have been modified, some of them many times. The atom, for instance, once generally accepted as the smallest division of matter, is now seen to be a veritable solar system, with a central "sun" and "planets," numbering perhaps to a hundred. The tube of every radio set establishes the certainty of this conception. And the facts shown there, and others like them, were before our eyes all the time that we were so certain the atom was indivisible; for who had not observed the blackening of an electric light bulb? Probably the most certain thing, in scientific experience, is that all judgments, however they may originate, will be modified in the future.

Next, it is the scientific conception that errors are inherent in everything;

and the accuracies of science are derived by analyzing those errors and assigning to them probable values. The sources of error are such as the apparatus, the observations, the observers, the processes or anything else that may tend to color or distort the result. The scientist analyzes his errors, not by comparing them among themselves, but by calculating the changes they produce in the result; thereby obtaining a figure that is known as the "probable error" of the result. For instance, if it is desired that a result shall be accurate to one per cent., then errors in contributing quantities that might change the result less than one tenth of one per cent., will not, on the whole, disturb the statement that the result is accurate to one per cent. So errors, if they can be kept within this limit, make no difference in the result, whatever their apparent size may be, large or small. Therefore, within such limits the scientist is able to make approximations wherein the differences between them and the true values will be indistinguishable in the result. Scientific accuracy is almost always limited by some one factor which, although determined with the utmost care, still affects the result far more than any of the other factors. But if, through improved facilities or the discovery of better methods, the accuracy of this difficult factor can be raised, then all the other factors are affected, because a higher standard of accuracy is now possible. What before may have been a reasonable approximation in some of the lesser factors—because indistinguishable in the result—is now no longer reasonable.

The difference between the apparent size of an error and the effect that it produces in the result may, perhaps, need some illustration. Let us consider the divergence of two lines as measured by the angle between them, which will bring out this comparison.

Suppose a man is lost in a wood, clouds completely obscuring the sky; and after walking some time he comes upon an object, say a toy compass, which he recognizes as his own, lost an hour before. He has been traveling in a circle. But the compass, however inaccurate, will get him out; for by means of it he will be able to follow the course he intends, a general easterly direction. It does not matter that the angle of his course with the line of the compass needle is purely a guess on his part; nor that the knife in his pocket may affect the needle; nor that the magnetic north differs from the true north. Such errors are of no consequence, because, if he can stick to any course, approximately, instead of traveling in a circle, he will come to the edge of the wood. So here we have an extreme case; an error obviously large in itself, which, when applied to the purpose at hand, becomes indistinguishable in the result.

The other extreme, a small error but which makes a large difference in the result, may be seen in artillery fire. In this, at certain positions, the slightest change in the angle of elevation of the gun, even a hair's breadth on the setting scale, will make a difference of many feet in the point where the shot strikes—it is the difference between a hit, and no hit.

The essential features for determining the confidence that may be placed in a result, its freedom from reasonable doubt, by the scientific method, are three: (1) that no stone small remain unturned where a source of error may lie concealed—a question of method; (2) that the effect of each error shall be judged, not by its apparent size, but by the amount of change it produces in the result, and this compared with the result taken as a whole—clearly a question of fact; and (3) that the standards of certainty of any given time shall not exclude the probability of future modification. It is upon these points that the divergence takes place between the methods of science and those of law. If gauged by the scientific standards, it would seem that the law did not always take into consideration, in appraising error, sources where science finds error to exist; that it puts too much emphasis, at times, upon the apparent size of an error, as distinct from the effect that the error produces in the result; and, particularly as regards the death penalty, that it makes no allowance for the future modification of the error that it finds.

The scientific conception of error, then, if applied to the interpretations of law, would introduce there a doubt, or a degree of doubt, that perhaps had not been recognized before. It would look for error not only in the evidence, but in the processes of securing and bringing out the evidence as well; it would look for a source of error in the relative abilities of counsel who present the evidence; it would examine the "personal equation" of the various individuals who might be concerned in a judgment; and it would challenge the capacity of human beings to form judgments that may not be subject to future modification.

To ignore important elements of the "probable error" that the scientific point of view imposes upon judgments, whether of judges or juries or of others, and at the same time to imbue them with an infallibility and permanence commensurate with death, is totally incompatible with the conceptions and experiences of science. Under these conditions the term "freedom from reasonable doubt" becomes, to the scientific mind, illusive and meaningless. And even if it were possible to reconcile many divergent views of science and the law, there would still remain—while the death penalty remained—the very reasonable doubt as to what the future may bring forth.

So, it appears, that scientific conceptions and methods would give an interpretation of reasonable doubt which, if recognized in law, would render the death penalty no longer a rational adjudication.

But after all, the conflict between the death penalty and scientific reason does not rest entirely upon the scientific point of view; it would seem to lie directly in the facts themselves. Accepting it as a fact that the processes of common law must be rational ones; it is also a fact that a process intended to eliminate doubt, which leaves certain known sources of doubt—particularly the future—uninvestigated, is not a rational process, and, therefore, can not be the common law. And how can a structure supporting the death penalty rest upon that foundation?

ERWIN F. SMITH—A YOUNG MAN'S IMPRESSION

By DONALD CULROSS PEATTIE

"WELL, go talk to Smith about it!" said my volatile chief, as he rolled down the top of his desk, crammed on his hat and strode off to a meeting with Vernon Kellogg or Walter Swingle or some other of his confreres.

I stood looking around the empty office, hung with pictures of Frank Meyer in Shantung and Rock in Burmah on the trail of chaulmoogra, and Popenoe on the Andes. I felt a bit blank and wondered if I had not been treated to a bit of irony. "Go talk to Smith about it!" Who, pray, was Smith?

I had a scheme, a wild plan that I am still not weaned from, a foolish notion that since the galls from which tannin is obtained are in a sense disease reactions of plants, it might be possible by growing certain vegetables in pure cultures to inoculate them with some disease, sufficiently virulent and yet sufficiently benign, to give us a continuous supply of the best tannic acid. I took the idea to David Fairchild, always open to fresh viewpoints. He listened as long as he could. Then "Go talk to Smith," said he.

So I went out in the corridor and asked up and down for Smith.

"Oh! Erwin F. Smith!" said every one.

That was something different. Yes, I had heard of him, had indeed read his book on the bacterial diseases of plants some years before in college, had heard his name reverently pronounced. Erwin F. Smith, pioneer of the bacteriology of the vegetable kingdom, the man who a generation ago was laughed at for predicting that it would be found that plants had more bacterial diseases than man, and lived to see his prediction more than fulfilled. Yes, I knew who that Smith was. And taking my hat gingerly in my hand, I almost tiptoed into his laboratory.

I looked some time around among the shining autoclaves, the racks of cotton-stoppered tubes, the simmering kettles of culture media, and the piles of books, before I discovered a short man, with handsome silver hair and beard, cheeks pink as a child's, seated, in immaculate laboratory clothes, quietly reading behind a big desk. I mention these trivial details because, as it happened many times as I subsequently entered his office, I never found him in any other posture or different in appearance. Always the milieu of bubbling vessels and sterilizers, always the little man in spotless attire, never flying around his laboratory, never appearing to labor, ever deep in a French or German book.

But however deep his attention, he never pulled himself out absent-mindedly, but on that first occasion as on all others he looked up quickly, and I found myself gazing into the most brilliantly blue eyes I ever saw. Their depth was unfathomable, and a light of humor sparkled there unfailingly. Upon seeing me he smiled as though I were an old acquaintance; the smile, I was about to say, was saint-like—more precisely, it was intensely and beautifully human.

I introduced myself briefly and started to blurt out my ideas. "I have a plan—"

"Good," he said. "Where were you born?"

I told him and tried to get on with my story.

He wrote down my birthplace in a little notebook, and then hazarded my age at twenty-four. I admitted it, but still I was not yet allowed to have my say. My name had to be spelled out carefully, and when he had it down in detail, he suddenly astonished me by asking how my mother's cousins were! After that fifteen minutes were consumed in talk about his old town of Lansing, Michigan, his relatives and mine there. The conversation worked around to my years at Harvard and the men under whom I had studied. That led to the Office of Foreign Seed and Plant Introduction and what I was doing there (all this noted down from time to time) and then at last I was permitted to try to "sell" my wild-cat scheme about tannin.

Again, I may justify the relation of these details by avowing that it appeared, later, to be his invariable practice to save his memory by putting down in a desk book the humans and their problems that came to him, just as a botanist saves a specimen of a plant. His desk book ought to make interesting reading; it must be a sort of herbarium of humans.

The most imaginative flights in my plan did not appear to startle this mild little man, this man who was daring to believe things that were utterly unorthodox in science (I refer to his open-mindedness towards the possible organic cause of animal cancers). He heard me out sympathetically, offered to help me, and sent me away loaded with books, reprints, manuscripts and articles bearing on that subject and on many in which he was interested more than I.

A few days later a letter came from a stranger concerning tannin. He mentioned Smith's name, and I realized that my correspondent too must have breezed into that laboratory, where Smith fumbled back in his notebook, discovered my name and whereabouts, and put us in touch.

When next I entered Smith's rooms I found, to my surprise, that I had to explain myself all over again. This was a bit chilling; but soon I realized that a mind so deep in philosophic ideas could not be burdened with remembering details like myself. I did not allow him, however, to write me down afresh in his notebook, and he laughed boyishly at the joke on himself when I found for him the entry concerning me, of several months before. I have forgotten what I came to talk of that day, but I know that his mind was just then full of Pasteur, whose biography he had just translated into English. Somehow he gave me an insight into the *esprit* of the French chemist who turned out to be a biologist that I have never forgotten. It fortified me against the superficial, slurring impression which the public has recently been given in that bit of able journalism, "The Microbe Hunters."

Some months later I attended a dinner of the Washington Botanical Society given in honor of Smith's birthday—his seventieth, I think. The dinner would have been dull as usual but for the revelation of a man I had now learned to know as truly great. Smith was so modest, so painfully modest, that he blushed almost continuously while on his feet before an audience of men younger and less eminent by far, for the most part, than he. He laughed nervously, stammered sometimes and was plainly glad to break away after the dinner.

Yet in the fashion of people who are simply modest, he talked with a quality of surprising frankness. His words were an *apologia pro vita sua,* charmingly candid in their delight at his ripe old age and the years of solid accomplishment, humorous in the fashion that is called tongue-in-cheek, unabashedly interspersed with quotations from the poets, his favorite lines quite evidently being those of Browning—

> Grow old along with me,
> The best is yet to be,
> The last for which the first was made. . . .

He closed his talk with a sonnet of his own, offered after Browning, Tennyson, and I think Shakespeare, with no more apology than a smile. The sonnet did not need apology, however. Later I learned that he was the author of a volume of poems, and if none of them take rank as literature, they are all pervaded by the sweetness, sincerity and good taste of their author. It is inviting the scorn of the littler men in science to have artistic tastes or fanciful mental play. This scorn apparently did not touch Erwin F. Smith any more than he feared an unorthodox method in experiment.

Some one else will write his biography. I do not know when or where he was born nor very much of his personal life. I have not read all that he wrote, nor will I ever accomplish that. He died in Washington, April 6, 1927; that date is the only one I know in connection with the finest, kindest and broadest scientist I ever met. His pride in his age was only equalled by his love of youth and tolerance of it. Of that love and tolerance I have had very good proof. Far too busy to remember me for long, Smith was a man whom I, a beginner in science, could never forget. He was the sort of man who makes young men say, "If I could, I would choose to be like him, fifty years from now."

THE PROGRESS OF SCIENCE

EDITED BY DR. EDWIN E. SLOSSON

Director of Science Service

THE SOLAR ECLIPSE OF JUNE 29

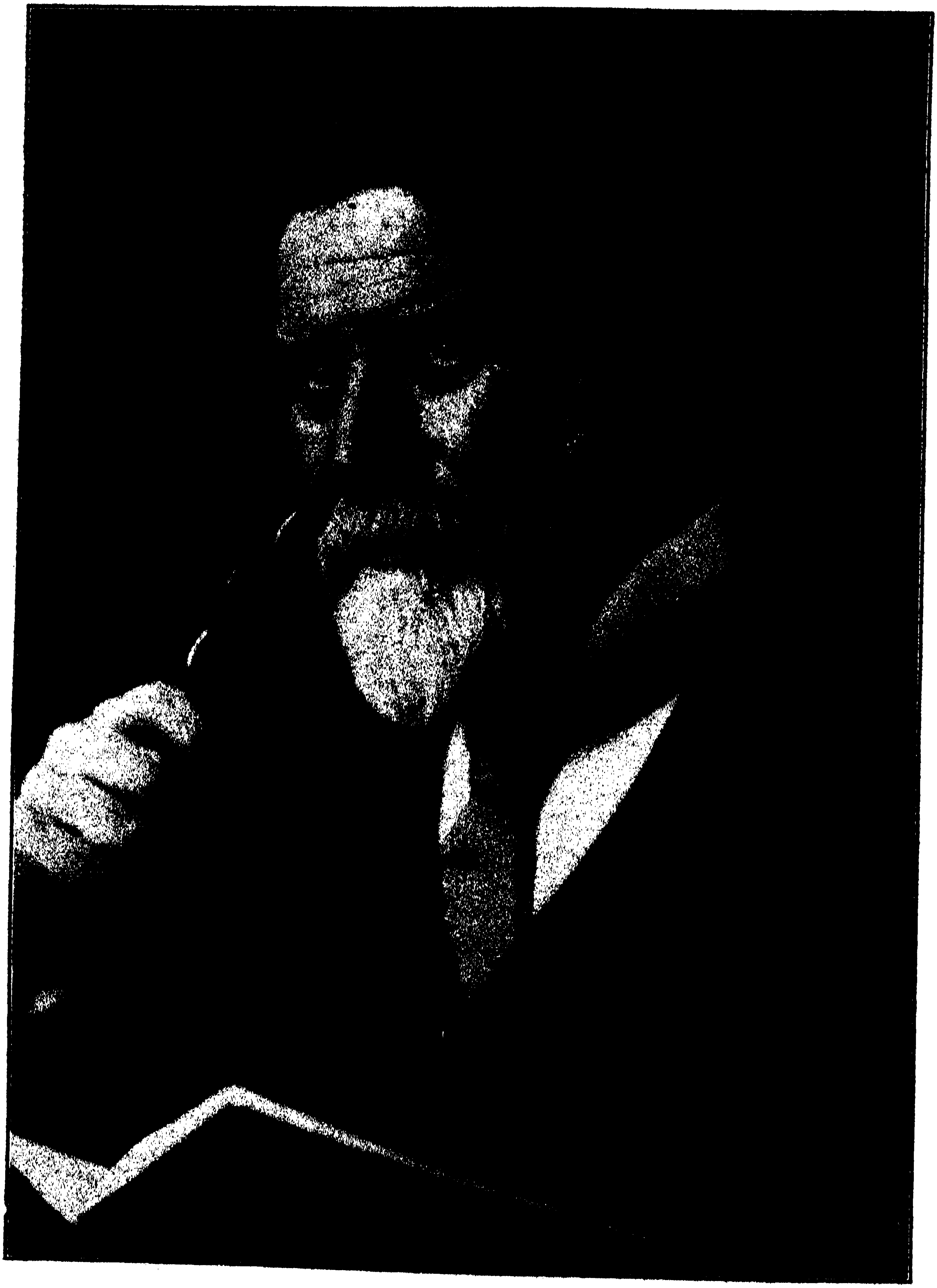
PEOPLE in England and Norway now have the opportunity of seeing the same rare phenomenon that was afforded to residents of the northeastern United States in January, 1925. Early on the morning of June 29, the shadow of the moon will sweep across England, the North Sea and the Scandinavian Peninsula, and people in this narrow strip will see the sun's disc obscured, while around it will shine the magnificent corona. That is, they will see it if the weather is clear, for there is only one chance in three that it will not be cloudy in England at the time.

But despite the probably poor weather conditions in England, no recent astronomical event has attracted so much popular interest. The last chances that Britishers had to observe eclipses were on May 2, 1715, and May 22, 1724. Both of these were observed by the great astronomer Halley, who is known to us as the discoverer of the periodic character of Halley's comet. Evidently there was some fear that the people of England would be unduly alarmed over the eclipse, for in a public announcement about it Halley said: "The like Eclipse having not for many ages been seen in the Southern Parts of Great Britain, I thought it not improper to give the Publik an account thereof, that the sudden darkness, wherein the Stars will be visible about the Sun, may give no surprize to the People, who would, if unadvertized, be apt to look upon it as ominous, and to interpret it as portending evill to our Sovereign Lord King George and his Government, which God preserve."

That eclipse of 1715 was visible from London and fortunately clear weather enabled Halley to observe it. Evidently he was very much impressed with the strangeness of the occasion, for he wrote afterwards of the "chill and damp with which the darkness of the Eclipse was attended, of which most Spectators were sensible and equally Judges," and the "Concern that appear'd in all Sorts of Animals, Birds, Beasts and Fishes upon the Extinction of the Sun, since ourselves could not behold it without some sense of Horror."

The eclipse of 1724 was also observed by Halley, but since then England has not been favored with an eclipse until this year. If clouds prevent observations this month, British astronomers will have a long wait ahead of them for the next eclipse, because it occurs on August 11, 1999. Then it will just touch the southwestern tip of Cornwall.

Norway seems about the best location, and that is where many of the astronomers who want to observe it are locating their instruments. Of course the English astronomers are making every preparation to watch it, in the hope that it will be clear, but Professor Samuel A. Mitchell, of the University of Virginia, who will head the only American expedition, has gone to Fagernes, in Norway. With him is Dr. Harlan T. Stetson, of Harvard University.



ERWIN F. SMITH

OF THE UNITED STATES DEPARTMENT OF AGRICULTURE, IN WHOSE DEATH AMERICA HAS LOST ITS MOST DISTINGUISHED PLANT PATHOLOGIST

SCIENTIFIC AIDS TO AVIATION

WEATHER maps in eight layers, showing what conditions the aviator may expect when he flys both low and high are now being made regularly as a part of the official government weather report. Ground weather observations alone have been found to be inadequate for flying use, and the high altitude observations have also been found useful in making the regular weather forecasts. In fact, the weather seems to brew at the higher levels and the observations, obtained by small balloons and kites, often give information unobtainable at the level of the earth's surface.

The data used in the upper air weather maps come to the Weather Bureau from thirty-five balloon stations throughout the country. There will be eight more after July 1. The Army has eighteen, while the Navy has ten balloon stations and one airplane observer. The Weather Bureau also receives air aloft reports of temperature and humidity from five stations where kites are sent up with meteorological instruments. As kites are dependent upon wind the Weather Bureau is about to try out a small captive balloon, just large enough to carry the necessary instruments, at Due West, S. C., for use when the air is "light." Helicopters will probably replace balloons and kites in the future.

Bumpy air, which makes rough riding for flyers, is clearly shown by these kite reports. One recent report from Grosbeck, Texas, showed three strata of air in an altitude of 1,800 meters. The complete aerological observation map gives wind direction, velocity, kind and direction of clouds, and visibility as at surface, 250 meters above, 500, 1,000, 1,500, 2,000, 3,000 and 4,000 meters above. The balloons sometimes achieve much higher altitudes. One in Washington climbed 22,000 meters. The origin of the wind, whether polar or tropical, is also known to the Weather Bureau and aids in weather forecasting.

As soon as Congress makes the necessary appropriation the U. S. Weather Bureau intends to take over the broadcasting of weather conditions now carried on from the bureau by the Navy through the Arlington Radio Station to all parts of the world.

"Flight surgeons" is the term used to designate a new class of specialists brought into being by the rapid advances of aeronautics since the world war. It has been tragically demonstrated that not everyone who wants to can fly and it is the job of these specially trained exponents of aviation medicine to spot such individuals before they get into the air, according to Major L. H. Bauer, of the U. S. Army Medical Corps. "An immense amount of work has been done, both from the experimental and practical sides, in this country and abroad," Major Bauer explained. "As a result of this work the percentage of aviation accidents due to physical causes has decreased in a surprising manner."

The outstanding essentials in the selection of a flyer, he explained, are good eyes and good nervous stability, quick reaction and coordination. By good eyes are meant not only normal vision and absence of color blindness but literally the ability to "see out of the corner of his eye," for in flying it is quite often necessary to know what is happening at one side when it is imperative to keep "eyes front" to see what is coming straight ahead.

Quick reaction time is essential because the flyer frequently has to meet a situation where almost automatic reaction is needed. The ear in spite of its connection with the sense of balance, is not now considered of great importance

MEDALISTS OF THE FRANKLIN INSTITUTE

The Medal Meeting of the Franklin Institute, Philadelphia, was held on May 18, when presentation of medals was made to several leading American men of science. The photograph shows, from left to right, Professor Edward L. Nicholas, of Cornell University; Dr. W. D. Coolidge, of the General Electric Company; Professor Harlow Shapley, of Harvard University, who received the medal for Dr. George Ellery Hale, honorary director of the Mount Wilson Observatory; Dr. O. C. Kiep, of the German Embassy, who received the medal for Professor Max Planck, of Berlin, and Professor Dayton C. Miller, of Case School of Applied Science in determining the physical status of an aviator.

After flyers are selected they are classified with respect to their ability to attain altitude, into two groups, fainters and non-fainters. The decreasing supply of oxygen in the far upper reaches produces physiological changes in the body to which different types react differently. Symptoms develop insidiously and the aviator may reach the fainting stage without realizing that he is not in a state of perfect well-being. Consequently a test has been worked out whereby flyers are grouped according to their altitude reaction, into classes A, unrestricted, B, restricted to 15,000 feet, and C, restricted to 8,000 feet. The limit of consciousness without oxygen is about 25,000 feet and with oxygen artificially supplied the limit of altitude is between 40,000 and 45,000 feet.

As ships put into good harbors, air traffic will surely be drawn to cities with well-designed airports, aeronautic experts believe. When aviators reach Atlanta they find on the top of one of the tallest buildings great letters spelling "Atlanta" and an arrow pointing the way to the municipal landing field.

The United States is following Germany, France and England in acquiring and improving municipally owned landing fields. For the purpose of perfecting a working organization for immediate development of American air fields and airways a National Conference for the Development of Commercial Aviation is being held at St. Joseph, Missouri. Porter H. Adams, of Washington, D. C., president of the National Aeronautic Association, is chairman of the conference.

As aeronautics expands commercially every city will need an airport. The requirements are that it shall be centrally located, easily approachable from all directions and by all methods of ordinary transportation. It should be large enough to be adequate for the increased needs of the future.

The development of emergency landing fields approximately every twenty-five miles along airways with boundaries indicated by lights, either acetylene or electric and with an incandescent searchlight type of light revolving in a horizontal plane has been the plan of the Post Office Department for several years. Floodlighted buildings and obstacles around the fields give a daytime perspective. It is believed that speed practically equal to that made during the daylight hours may be maintained at night over properly lighted and prepared airways and will make possible rapid transportation of mail, express and passengers for every section of the country.

THE EARTH INDUCTOR COMPASS

LINDBERGH attributed his success in keeping on his outlined course in his transatlantic flight to the earth inductor compass with which his monoplane was equipped. Regarding this instrument he wrote: "Laymen have made a great deal of the fact that I sailed without a navigator and without the ordinary stock of navigation instruments, but my real director was my earth inductor compass. I also had a magnetic compass; but it was the inductor compass which guided me so faithfully that I hit the Irish coast only three miles from the theoretic point that I might have hit if I had had a navigator. The inductor compass was so accurate that I really needed no other guide." In his flight to Germany Chamberlin was less fortunate in the use of the earth inductor compass and relied primarily on a simple magnetic compass. He deviated considerably from the course that he had laid out.

The working of an ordinary compass depends solely upon the interaction of two magnetic fields, while the principle of the earth inductor compass is based upon that of electromagnetic induction. In 1831 Michael Faraday discovered that when an electric conductor is moved across a magnetic field a current is generated in that conductor. In the case of this compass the electric conductor consists of a rectangular armature which is driven by a windmill; and the magnetic lines of force that are "cut" are those of the earth field. The electromotive force generated by an armature depends upon the position of the brushes on the commutator in relation to the direction of the magnetic field. In general if the line joining the two brushes is perpendicular to the magnetic lines of force, the maximum potential is obtained; when they are parallel the potential is zero. The working of the compass hinges upon this fact. The potential depends upon the angular relation between the brushes and the direction of the earth's field. That is, the output of the generator is a function of the angle between the position of the brushes and magnetic North. The "indicator" or "compass hand" is simply the needle of a sensitive galvanometer, the position of which indicates the relative amount of electromotive force generated. A device mounted on the instrument board termed the "controller" is connected to the brushes by a shaft in a casing. Rotation of the controller causes a corresponding rotation of the brushes of the generator. Dials upon the face of the controller show the angle through which the brushes have been oriented in relation to the airplane.

The usual method of steering by this compass is to set the desired heading on the controller and then to steer to keep the indicator on zero. An unknown direction can be determined by rotating the controller dial until the indicator reads zero, when the course will correspond to the point at which the controller dial stopped. This dial has 30 divisions, each one corresponding to 10 degrees on the compass, making in all 360 degrees. Operating at normal speed, the generator output will be sufficient to cause a deflection of the tip of the hand of the indicator of not less than 0.4 mm. for a 1° departure from course, and a deflection of not less than 10 mm. for a 30° departure from course.

There are two outstanding advantages of the earth inductor compass over the ordinary magnetic compass. First: the generator is mounted in the rear of the fuselage—so far distant from the motor that any magnetic fields created by it can have no effect on the deflection of the galvanometer needle. Second: the needle automatically always tends to return to the zero point through the action of a delicate spring. This compass is thus relatively unsusceptible to vibrations and other disturbances which tend to prevent the proper functioning of the ordinary magnetic compass.

Dr. Paul R. Heyl and Dr. Briggs, of the Bureau of Standards, constructed the first working model in 1920. After extensive tests by the Army Air Corps, further improvements were made and the instrument has withstood all the critical tests to which it has been subjected. It was then turned over to instrument makers for commercial production.

LANGLEY'S AERODROME

The first announcement of Langley's experiments with his aerodrome was made thirty-one years ago in the following communications:

THE EDITOR OF SCIENCE—*Dear Sir:* After having published some investigations in aerodynamics ("Experiments in Aerodynamics" and "The Internal Work of the Wind"), I have made further experiments on the practical application of these conclusions, in the construction of an aerodrome or flying machine, upon a scale sufficient to admit of the employment of a steam engine of between one- and two-horse-

AUGUSTIN JEAN FRESNEL

The French physicist, distinguished for his work on optics, the centennary of whose death occurs on July VD power. I have never given any account of these experiments, as I have wished first to attain such a complete control of the flight as would insure its being automatically directed in a horizontal course, in any desired azimuth; but in view of the demands upon my time, which render it uncertain how far I can continue my personal attention to the completion of this object, I have yielded to the request of my valued friend, Dr. Graham Bell, to authorize the publication of a general statement of the results thus far obtained.

Let me add, in explanation, that the scale of the construction did not admit of any apparatus for condensing the steam or economizing the water, which, therefore, could only be carried in sufficient quantity for a very short flight. This difficulty is peculiar to the scale on which the experiment is conducted, and does not present itself in a larger construction.

Professor Bell has shown me his letter, which follows.

Very respectfully yours,
S. P. LANGLEY
Washington, D. C., May 12, 1896.

THE EDITOR OF SCIENCE—*Dear Sir:* Last Wednesday, May 6th, I witnessed a very remarkable experiment with Prof. Langley's aerodrome on the Potomac River; indeed, it seemed to me that the experiment was of such historical importance that it should be made public.

I am not at liberty to give an account of all the details, but the main facts I have Professor Langley's consent for giving you, and they are as follows:

The aerodrome or "flying machine" in question, was of steel, driven by a steam engine. It resembled an enormous bird, soaring in the air with extreme regularity in large curves, sweeping steadily upward in a spiral path, the spirals with a diameter of perhaps 100 yards, until it reached a height of about 100 feet in the air at the end of a course of about half a mile, when the steam gave out, the propellers which had moved it stopped, and then, to my further surprise the whole, instead of tumbling down, settled as slowly and gracefully as it is possible for any bird to do, touched the water without any damage, and was immediately picked out and ready to be tried again.

A second trial was like the first, except that the machine went in a different direction, moving in one continuous gentle ascent as it swung around in circles, like a great soaring bird. At one time it seemed to be in danger as its course carried it over a neighboring wooded promontory, but apprehension was immediately allayed as it passed 25 or 30 feet above the tops of the highest trees there, and ascending still further its steam finally gave out again, and it settled into the waters of the river, not quite a quarter of a mile from the point at which it arose.

No one could have witnessed these experiments without being convinced that the practicability of mechanical flight had been demonstrated.

Yours very truly,
ALEXANDER GRAHAM BELL
1331 Connecticut Avenue,
Washington, D. C., May 12, 1896

THE GUGGENHEIM SCHOOL OF AERONAUTICS OF NEW YORK UNIVERSITY

GROUND was broken on October 22, 1925, at University Heights in New York City, for the Guggenheim School of Aeronautics of New York University. The building which had long been a dream in the minds of the university authorities came about through the generosity of Daniel Guggenheim who, in making his offer and presenting his check for $500,000 to Chancellor Elmer Ellsworth Brown, was actuated by a desire "more quickly to realize for humanity the ultimate possibilities of aerial navigation" and " to give America the place in the air to which her inventive genius entitles her."

The new building of the Daniel Guggenheim School of Aeronautics, the construction of which began in the fall of 1925, was formally opened on June 4 of this year. A large gathering of prominent men identified with the aviation industry and the government inspected the building from cellar to roof. Mr. Daniel Guggenheim spoke to the visitors and the Honorable William P. MacCracken, assistant secretary of commerce, carried the good wishes of the government to the officials of the school and university.

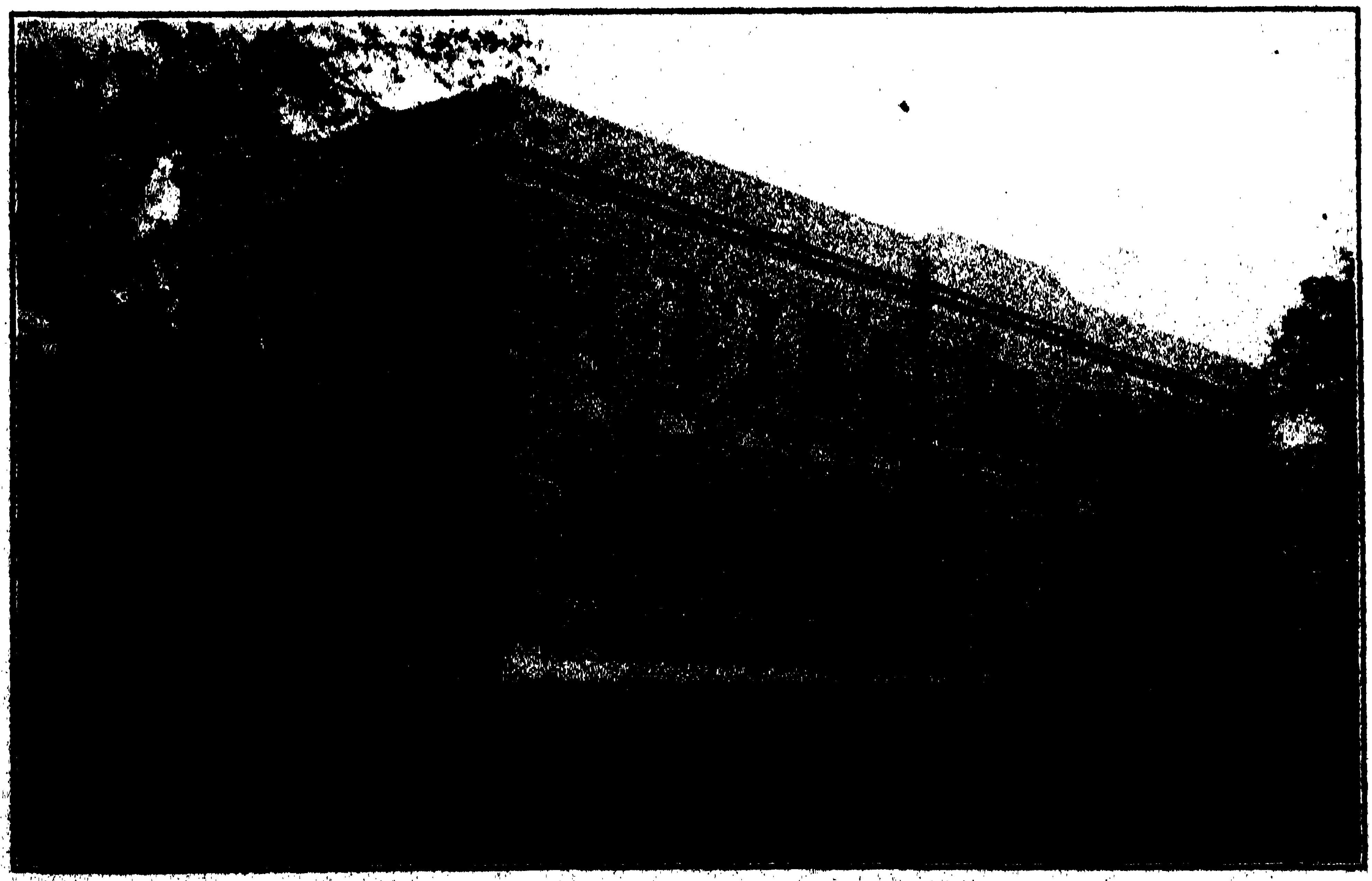
In 1921 the growing importance of aviation led to an investigation of its possibilities by the department of mechanical engineering of the university with the result that a course of lectures in aeronautics was given to senior students during the academic year of 1921–22. The success of these lectures led to the incorporation of courses in aeronautical engineering as a senior option with an introductory course in aerodynamics and airplane design in the junior year. The first class was graduated in 1924.

In order to place aeronautical work of the university on a permanent footing, an advisory committee formulated plans for a permanent endowment which the generosity and far-sightedness of Mr. Daniel Guggenheim quickly made possible.

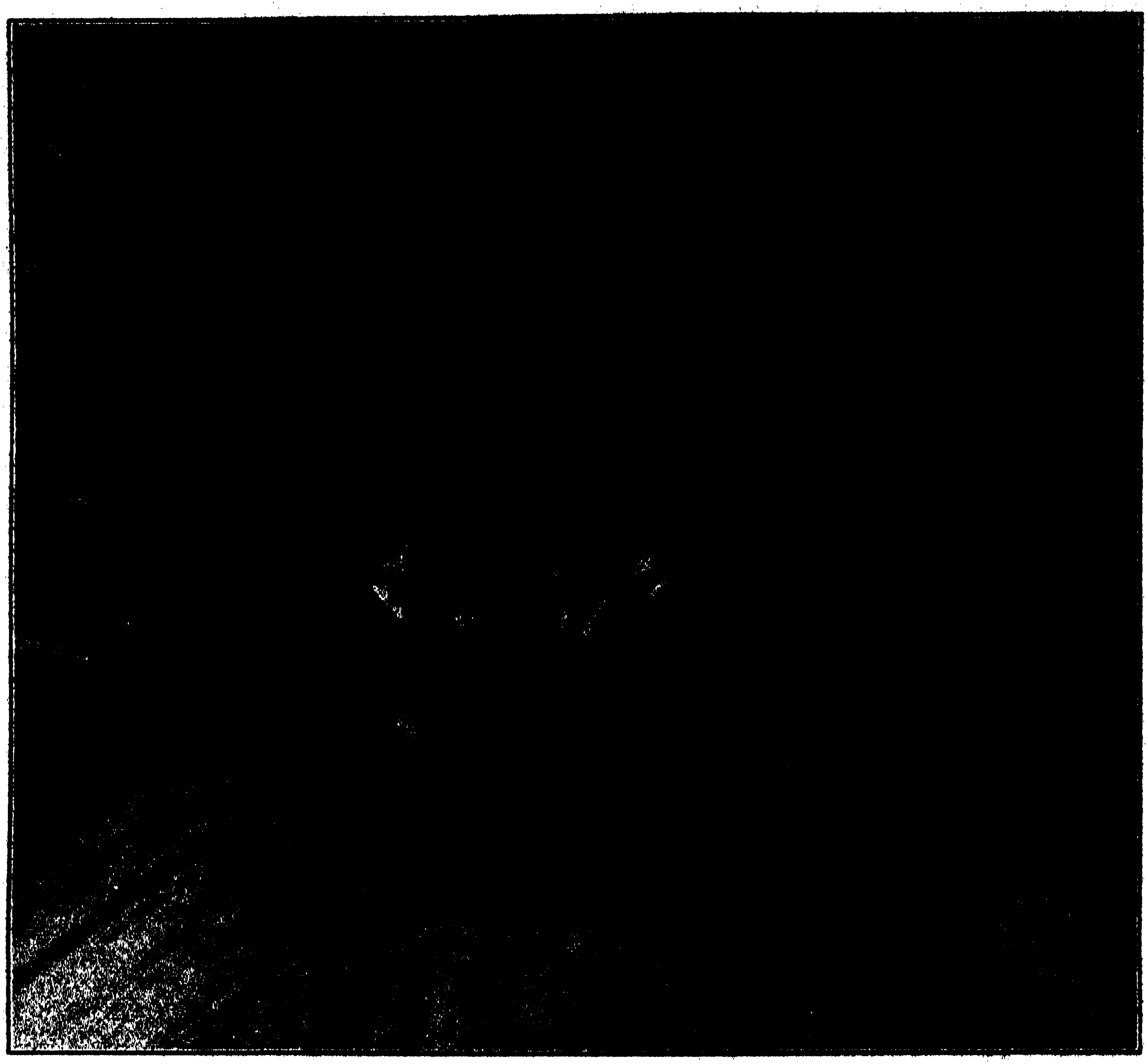
The new building which is located on the south side of the 50-acre campus of the university at University Heights, the Bronx, in New York City, contains one of the largest wind tunnels in the world wherein tests will be held involving models of airplanes and other aerial dynamic structures.

The air will be driven through the wind tunnel, which is 110 feet long and 55 feet wide, by an eight-bladed aluminum propeller, 14 feet in diameter and driven by a 300 horse-power motor which will create a gale force of 100 miles an hour. This will permit of the most exact results which will accurately forecast flying conditions affecting full-sized planes.

The building, which is of light brick trimmed with stone, is similar in architecture to the other buildings on the campus. In addition to the wind tunnel the building contains a structural laboratory where flying instruments will be tested before they are used in checking aeroplane action in flight; a shop where models of planes, accurate to one two-hundredth part of an inch, will be built; a large drafting office; a laboratory for testing aeroplane engines; an aeronautical library; an aircraft museum; class rooms and offices. The Air Unit of the University Reserve Officers



THE GUGGENHEIM SCHOOL OF AERONAUTICS OF NEW YORK UNIVERSITY



WIND TUNNEL

OF THE GUGGENHEIM SCHOOL OF AERONAUTICS

Training Corps also has their headquarters in the building.

Charles H. Snow is the dean of the College of Engineering and Professor Alexander Klemin, professor of aeronautical engineering, is in direct charge of the work in the new School of Aeronautics.

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THE HISTORY OF THE ALPHABET

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THERE is no story more romantic than the story of the alphabet! Interwoven in this tale is the upward struggle of mankind—the search of adventure in distant lands, the trading expeditions to alien shores, the quest of dominion over alien tribes and races, and, most significant of all, the gradual expansion of human thought.

Think of the power which lies hidden in those apparently insignificant symbols which we call the alphabet! It is the carved, chiseled, engraved, written or printed word which preserves and advances civilization.

It is asserted that the discovery of fire was the greatest forward step of man, as it gave him comfort, protection, light and a means to master nature; but greater than this was the birth of an art which recorded man's thought and progress.

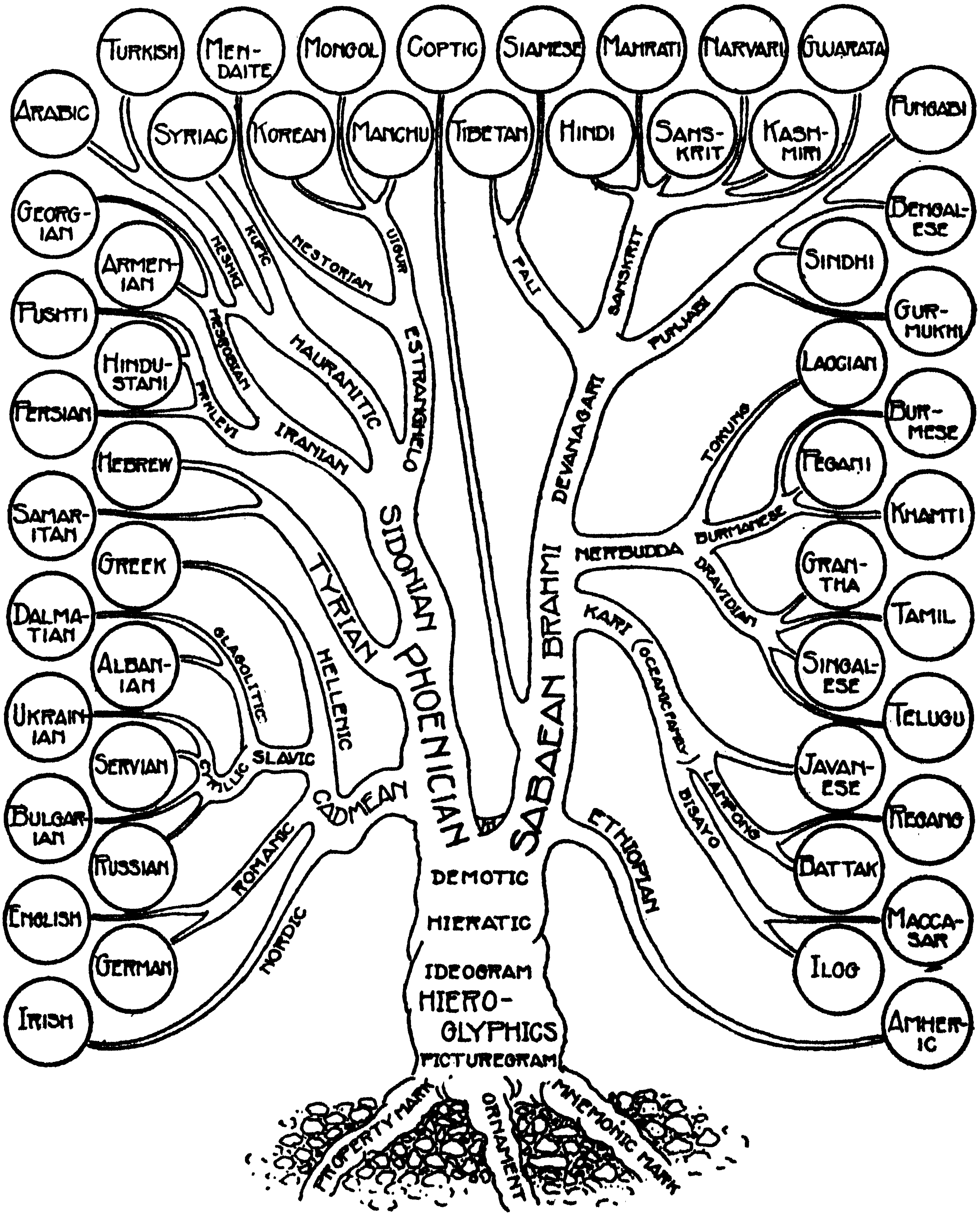
By this art man has achieved his cultural emancipation from a state of mere existence; this has enabled him to build the complex society of to-day, which depends upon the thoughts and works of our ancestors, for the "new things" of to-day required the "old things" of yesterday.

Whereas man at all times possessed the power of reasoning—that divine spark which separates him from the animal world and created the mental chasm never to be bridged—his progress has been slow. We find the development of the tool sluggish and hesitant: the masses always selecting the path of least resistance and timorously following in the footsteps of some more daring predecessor, driven only by dire necessity.

The idea of an alphabet did not come suddenly to the brain of some genius, but was slowly evolved during many generations and finally dawned hazily upon human consciousness. And to-day, after a few thousand years of practical use, man is still footstepping in precedents and has not found the courage to adopt an efficient alphabet. We still cling to archaic forms of spelling and burden our children with the complicated orthography by our refusal to progress—for:

The perfect alphabet should have a single character for each sound, and a single sound for each character.

Man copies, he has copied and keeps on copying! This human weakness illuminates the history of the alphabet. Whether Greek or Sanskrit, Russian or Siamese, German or Hebrew, we can trace all back to a common origin. From all four points our path leads to the cradle of civilization in and around Asia Minor. There we find during archaic times several forms of writing, hieroglyphics and cuneiform, developed from crude picture writing. In following the trail still further we find the ancestors of both and come then to the misty past where the tracks have been



THE FAMILY TREE OF ALPHABETS

The common source of all alphabets are the hieroglyphics of Egypt. From their simplified form, the demotic, the ancient Hebrew tribes borrowed their symbols which spread through the ages to all quarters of the globe, thus linking the alphabets of Ireland, Abyssinia, India and Mongolia and intermediate points into one great family.

erased from man's consciousness and of which no records have survived.

EARLIEST TRACES OF WRITING

Property marks

On nearly every prehistoric site the archeologist finds some symbols or characters, painted or chiseled on rocks or stone. Many of these markings are undecipherable—they are not pictures but characters which belong to no known alphabet. They are usually simple and may resemble some of our modern letters, such as I, T, A, Z or M. On pebbles in France, Switzerland and Germany, on fragments of pottery in Egypt, centuries before the dawn of civilization, and on rocks in the caves of Nevada, these markings have been made by the primitive savage.

Such symbols are assumed to indicate ownership, they were the property marks of the primitive savage and placed upon his utensils, tools and weapons—just as we are in the habit of putting initials on our fountain-pens and automobiles, ex-libris in books and monograms on tableware and jewelry.

If there were among the primitive potters one whose skill was greater and consequently his ceramic creations of better grade, such superiority was bound to become known; his pottery was a thing to be coveted, and in peaceful times his mark became a trade-mark because his goods were articles of exchange. So as time went by the property mark changed from denoting the possessor and became the trade-mark indicating the maker.

THE SECOND PERIOD OF WRITING

Mnemotechnic marks

As man became more sociable and began to trade with his neighbor, besides making war, there came a period when he needed some device for refreshing his memory regarding his transactions. Likewise, he may have wanted to send messages to distant friends. Here the trail becomes clearer, for we can observe the means employed by primitive races in historic times and assume that similar means have been used by the primitive savage of prehistoric time.

Among the primitive Australians we have a wooden stick with notches. The Peruvians had the quibu, strings of different colors with differently tied knots.

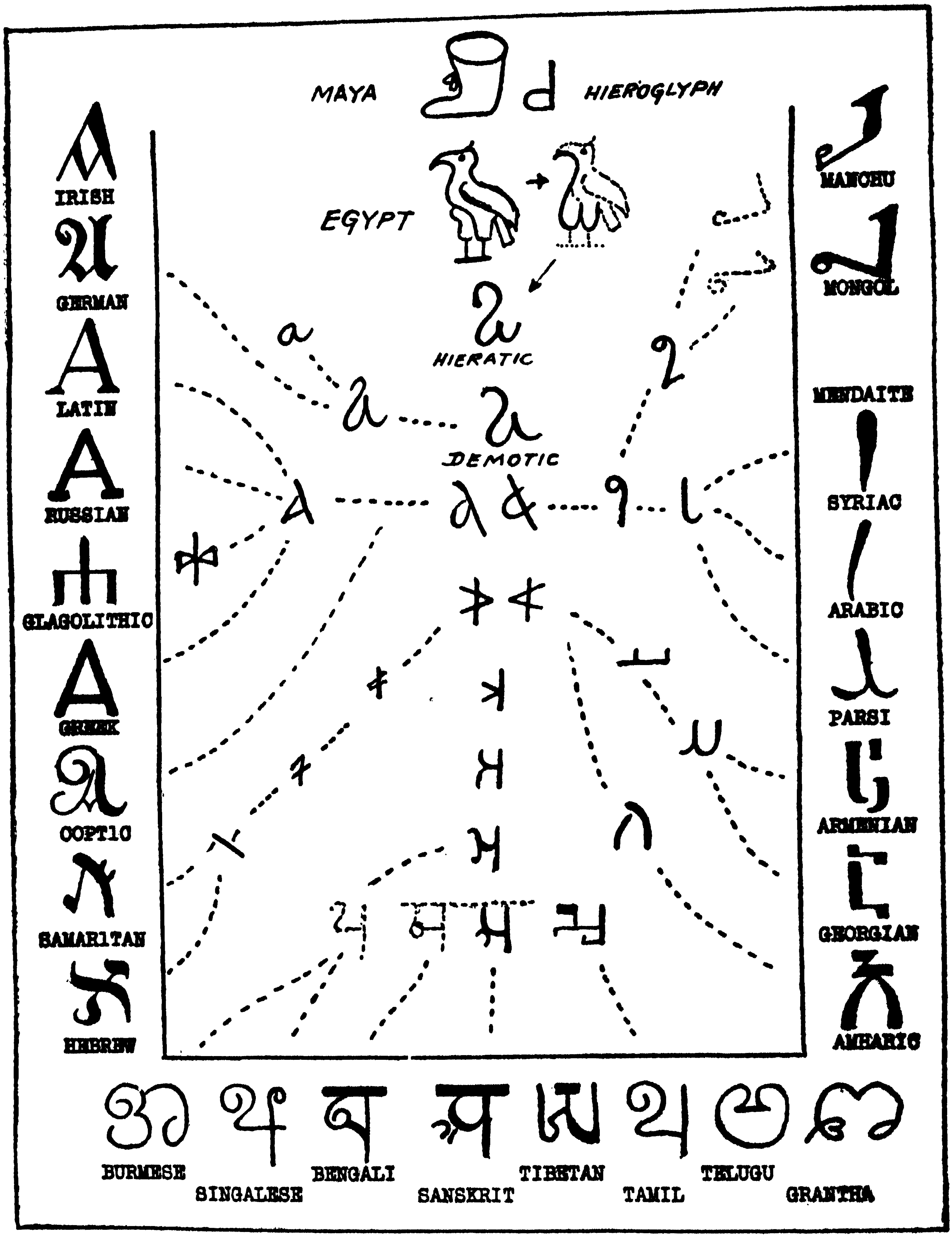
An illustration of a mnemotechnic device is also Robinson Crusoe's calendar—a short notch for weekday, a longer notch for Sunday. Or even a more realistic example is the custom of counting by strokes: ||||| ||||| |||. These marks may mean bunches of bananas or barrels of wine, cakes or cattles, and are thus void of meaning, except to those who made them. This is the distinguishing feature of all mnemotechnic devices, and there are many of them. The field is unlimited, even to-day we tie a string around our left thumb, knot our handkerchief, or put the watch in another pocket as a reminder of something which we usually forget.

Many of the mnemotechnic devices have become conventionalized, so that the receiver of a message stick or a quibu may guess at the meaning without the oral explanation of the messenger. Some of our present-day customs trace back to such conventionalized mnemotechnic devices. For example, the olive branch, offering salt, handing the key of the city, or even shaking hands as a sign of good will.

THE THIRD PERIOD IN WRITING

Picturegram

The mnemotechnic device was at its best undependable and indefinite and with increasing mental activity and social complexity man was forced to take the next step which led to the pictogram or picturegram. Man attempted to draw the likeness of the object. A hunt or battle, with so many slain and so many



A

The three strokes of A can be recognized in the Hebrew character as well as in the inverted K from which the Indian alphabets are derived. It loses the hook in Arabic and Syriac, lies on its side in Mongol and Manchu as well as in Armenian and Georgian and becomes rather fanciful in some of the Indian characters.

captured—crude pictures of animals or of men, with or without their heads—were sufficient to tell the tale.

Such pictures we can see in the museums on hides, ivory, pottery, wood and fabrics—the work of Indians, Eskimos, African and Australian tribes.

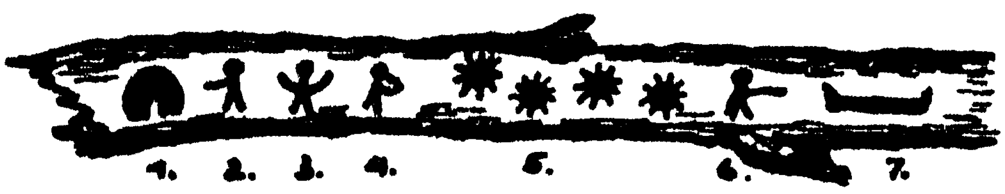
Records of the past indicate that the ancient tribes in Egypt, Assyria and China pursued the same method and that picturegrams were the oldest forms of writing.

Crude pictures are sufficient. And with frequent use the picture stories and picture messages become more conventionalized and simplified. Thus they developed into cuneiform characters in Assyria, into hieroglyphics in Egypt and into Chinese symbols in China.

The Fourth Important Step

Ideogram

Sooner or later the picture alone becomes insufficient to express the thoughts and ideas developing in man's consciousness. Man's thought grew from the concrete to the abstract—he conceived more complex and more highly developed ideas which reached outside the physical world. Thus pictures of objects became insufficient and the necessity came of taking another forward step in the art of writing—the development of the ideogram.



A PICTURE MESSAGE

A messenger can not be sent or spared, as all the men have gone on a long hunting trip and women, children and disabled men are left in the camp. The food gives out and the camp has to be moved before the hunters return. So they pack up and go and as there are no typewriters the stenographer will cut a piece of wood or bone with the above message, assuring and directing the hunters: (1) and (2) In the hut (3) nothing (outstretched arms have the universal meaning of nothingness) (4) to eat or drink. (5) Four suns (or days) (6) in this direction (7) by boat or canoe.

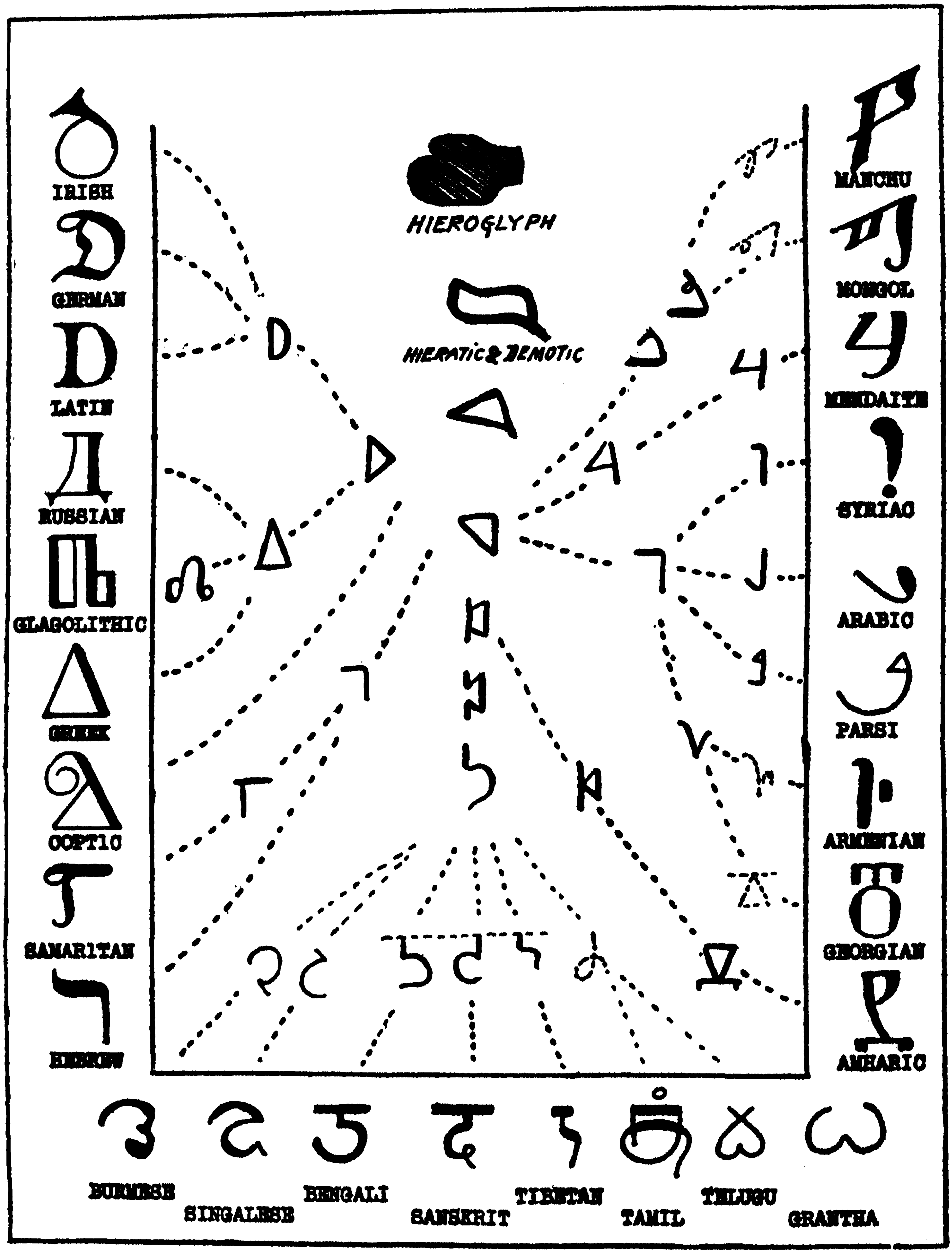
A MESSAGE STICK

A wooden stick with notches serves as a mnemotechnic device and we might imagine a native chief instructing his messenger as he cuts these notches: (1) That biggest notch—that's me—(2) these are my two brothers, and (3) these are my three boys. Now you go (4) five days' journey and invite (5) my neighbor chief and his three brothers, these four notches, to the initiation of my three boys which will be (6) in fifteen days.

Just as we reason from particular incidents the general behavior, so our early ancestors were ingenious in combining pictures of particular objects, to express a general idea for which he could draw no picture. This process is well illustrated in the history of the Chinese characters, which at the present time are but conventionalized symbols of object-pictures.

For example, the idea "light" is too intangible to be pictured. Some ancient Chinese philosopher solved the problem arbitrarily by combining the pictures of the "sun" and "moon." Thus by combining the concrete he reached the abstract—however still vague and uncertain, for "sun-moon" may just as arbitrarily mean "time" or a "24-hour-day." Numerous and interesting are these combinations, "two woman" means jealousy, and "three woman" stands for gossip.

Not only in China, but also in Assyria, in Egypt and in Central America, in cuneiform, heiroglyphic and Maya symbols this development of combining characters took place. So the number of ideograms multiplied and grew into thousands. Writing became a complicated art, mastered only by few. In time the true meaning of many of these ideograms became obscure, and the characters had to be learned by memory.

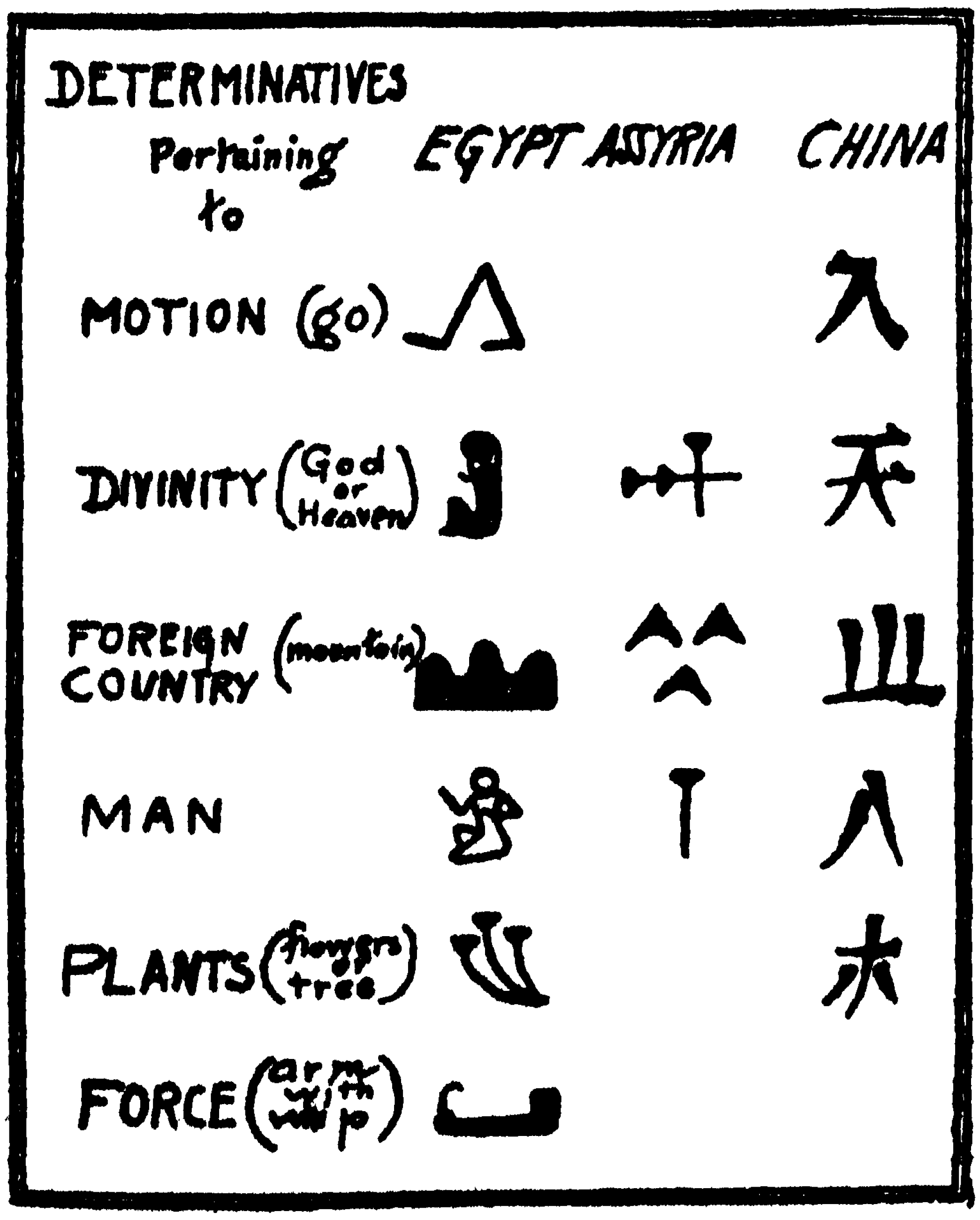


D

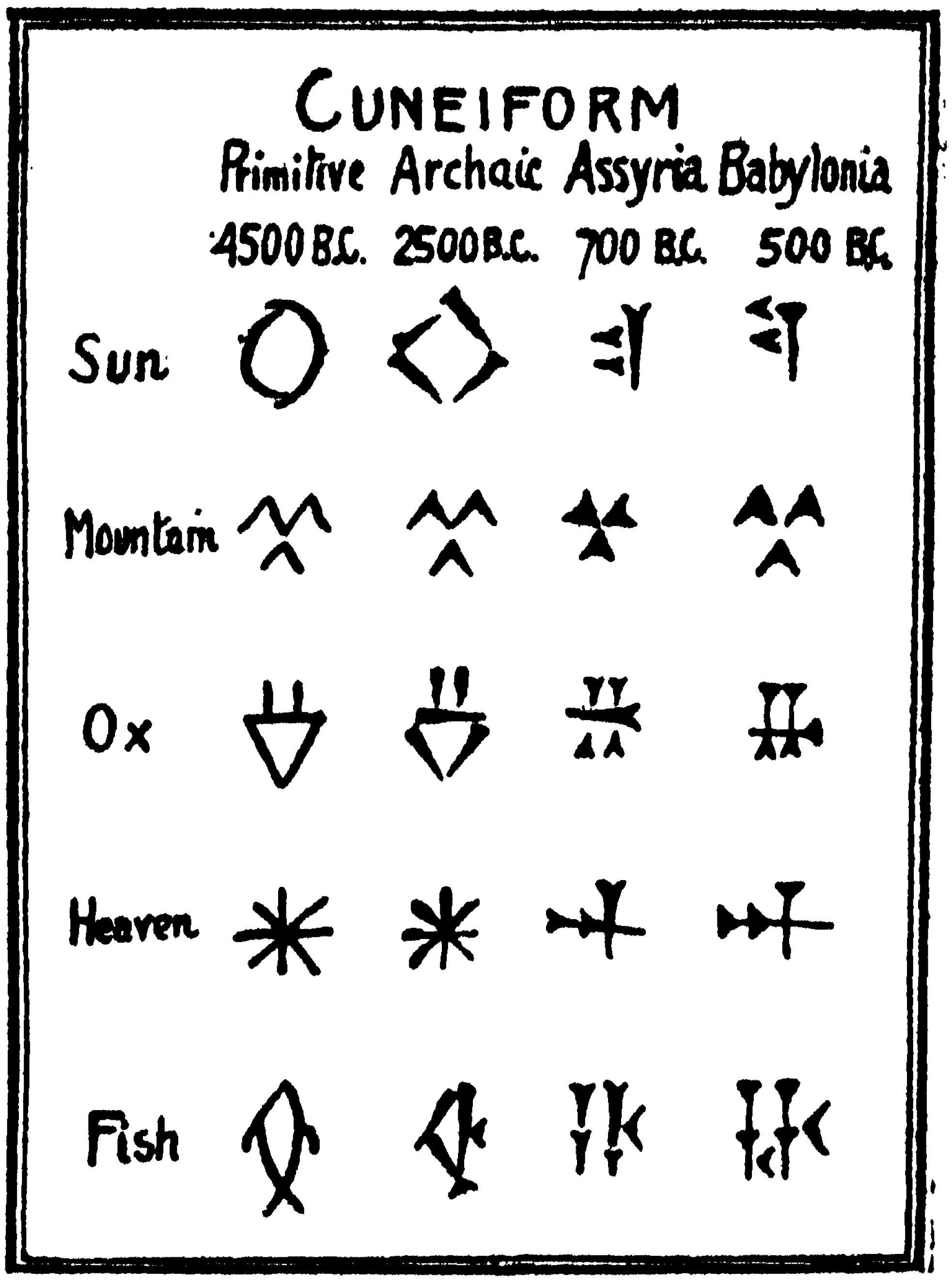
The letter D developed from a triangle, which loses its hypotenuse in Samaritan and Hebrew; becomes opened and rounded in the Indian alphabets; abridged in Syriac and Arabic; and fanciful in Manchu and Mongol.

Many are the shortcomings of the ideogram, and to make matters seemingly more easy, but in reality more complex, classifying symbols were added to the ideograms. These classifying symbols or determinatives were used to put the idea or object of the hieroglyphic into a certain group: all things concerned with man had a picture of a man attached to the ideogram, everything related to plants a flower or tree, to buildings, a house, to countries, a mountain; all ideas connected with motion, the symbol "go," usually a picture of two walking legs.

Writing was now an intricate art and began to exert its mighty power upon mankind. It became surrounded by mystery and sacredness in the minds of the masses, which was by no means intentional on the part of the few who could write and read. To the acute observative mind of the people the symbols became beings and spirits which made those who read them, usually the priests and scribes, "talk," and more wonderful yet, it made different priests at different times or different places "talk the same way." (Curiously enough, we still use the phrase, "What does it say?" and never inquire, "What does it read?" when we are puzzled by an undecipherable writing.)

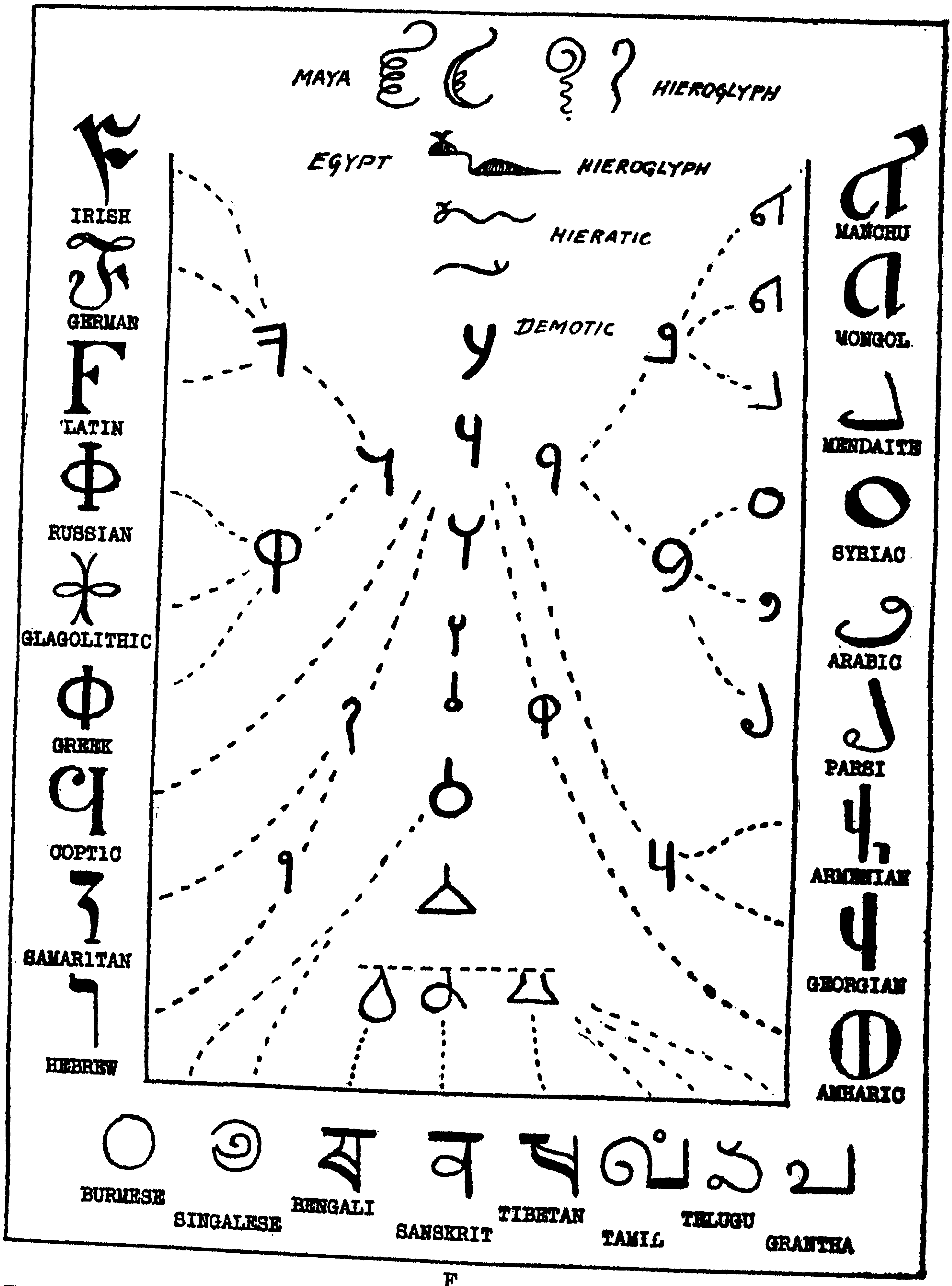


The shortcoming of the picturegram was realized in Egypt, Assyria and China, for an abstract idea can not be expressed by concrete objects. Thus it became necessary to place before or after a character a determinative, to indicate the group of things which the symbol should represent. This added to the complexity and confusion and made writing still more difficult.



The cuneiform writing likewise developed from picture writing. If there had not at the same period developed an alphabetic writing from the Egyptian hieroglyphics, it is very probable that the cuneiform characters would have become the basis of an alphabet.

Not all the primitive ideograms reached the perfection attained in Egypt, China and Central Asia. Indian picture-writings barely began to use determinatives and the Alaskan ideograms served mainly genealogical and religious purposes on totem poles.



F

The letter F and Ph traces back to the Egyptian hieroglyph representing a hissing snake and curiously the Maya hieroglyph depicts likewise a snake. In its development the demotic fork passes unchanged to the Coptic, Georgian and Armenian symbol, becomes double-forked (digamma) in the Latin, German and Irish F, and changes to a loop in many of the remaining alphabets.

Only the Egyptian hieroglyphics developed further into an alphabet—the Chinese remained in the *status quo* and became conventionalized into the modern characters used in China to-day. Assyrian and Maya writing died out, the first because progress was made with alphabetic characters close by, the second on account of political changes which destroyed the Maya culture.

Yet ideograms are still with us in the form of many symbols used in art, heraldry, church, fraternal organizations and daily life. The propeller and wing does not mean a propeller and a feathered wing but is the insignia of "aviation." In the political zoo we have the moose and elephant, in the international arena the lion of England, rooster of France, bear of Russia and the dachshund of Germany; likewise in the botanical garden grows the thistle of Scotland and the shamrock of Ireland, the cherry blossom of Japan and the lotus of India.

THE FIFTH AND FINAL STEP

Phonograms

The time came when the soul of poets, prophets and philosophers awakened and upon man's vision dawned the spiritual world of justice and God, of morals and ethics. During this epoch the great epics and legends of heroes and demons, of Good and Evil were created and the virgin soul of man burst forth in song and passed it on from mouth to mouth until the impulse of recording these more abstract thoughts overcame the inadequate means of writing. This led to the birth of the phonogram.

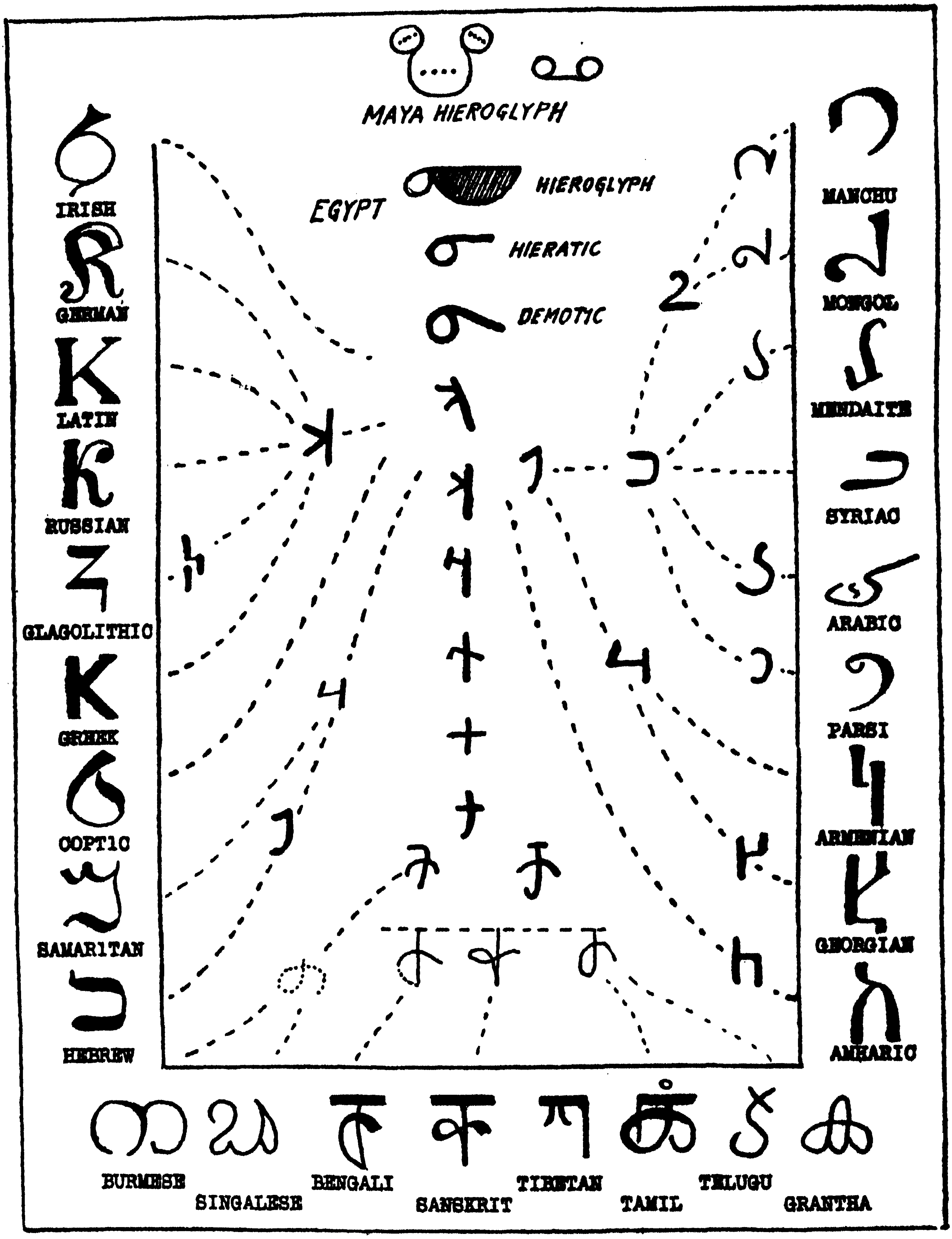
The phonogram was a conventional and arbitrary use of the picturegram. For instance, to convey the general concept of "charity" there would be an endless number of picturegrams depicting particular cases, but restricting the picturegram to the first syllable of the object depicted, we would phonetically spell the word by drawing a "CHAriot," a "RIver" or "RIbbon" and a "TIle" or "TIger." Thus the picturegram does no more indicate the object, but its first syllable. From the syllabary "cha-ri-ti" developed in time the consonant writing "ch-r-t" which still survives in Hebrew, Arabic and Turkish. But this consonant writing is likewise unsatisfactory, for "chrt" may just as well mean "chart," "chariot" or "cheroot." Hence in later times an auxiliary system of indicating vowels had to be adopted, from which sprang the consonant-vowel writing of the European races.

THE DEVELOPMENT OF THE ALPHABET

The hieroglyphics of ancient Egypt are the parents of all our modern alphabets. Whether these hieroglyphics have been developed by primitive Egyptian tribes or whether they have come from a still more remote form of writing, originating in the mysterious Atlantis, is doubtful. The later hypothesis is based upon the striking similarities between Maya hieroglyphics and Egyptian hieroglyphics, which would point to a common origin in the sunken continent of Atlantis.

But the immediate cradle of our alphabets stood in Egypt where the priest was the guardian of the secret of writing for recording political history and moral thought. Among the oldest of records is the moral concepts of Ptah Hotep, which dates around 3600 B. C. About eight hundred years later came the famous "Book of the Dead," which describes graphically the wanderings of the soul after death and the final judgment day on which the soul is weighed against a feather in the presence of Good and Evil and followed either by destruction or eternal happiness.

By this time writing had developed from the pictures to the ideograms and phonograms, and now came in addition to the already complex hieroglyphics an abbreviated form which was used as a cursive writing on papyrus, skin or wood. This was the hieratic or sacred



K

The letter K and its cousin Qu are both derived from the loop-like demotic character, which becomes angular when carved in stone. Irish and Coptic preserve the Qu-shape, while the Indian alphabets passed through a cross-shaped character; the Samaritan, and Armenian, metamorphosed from a figure resembling "4," which is reversed in Georgian, and turned upside-down in Amharic.

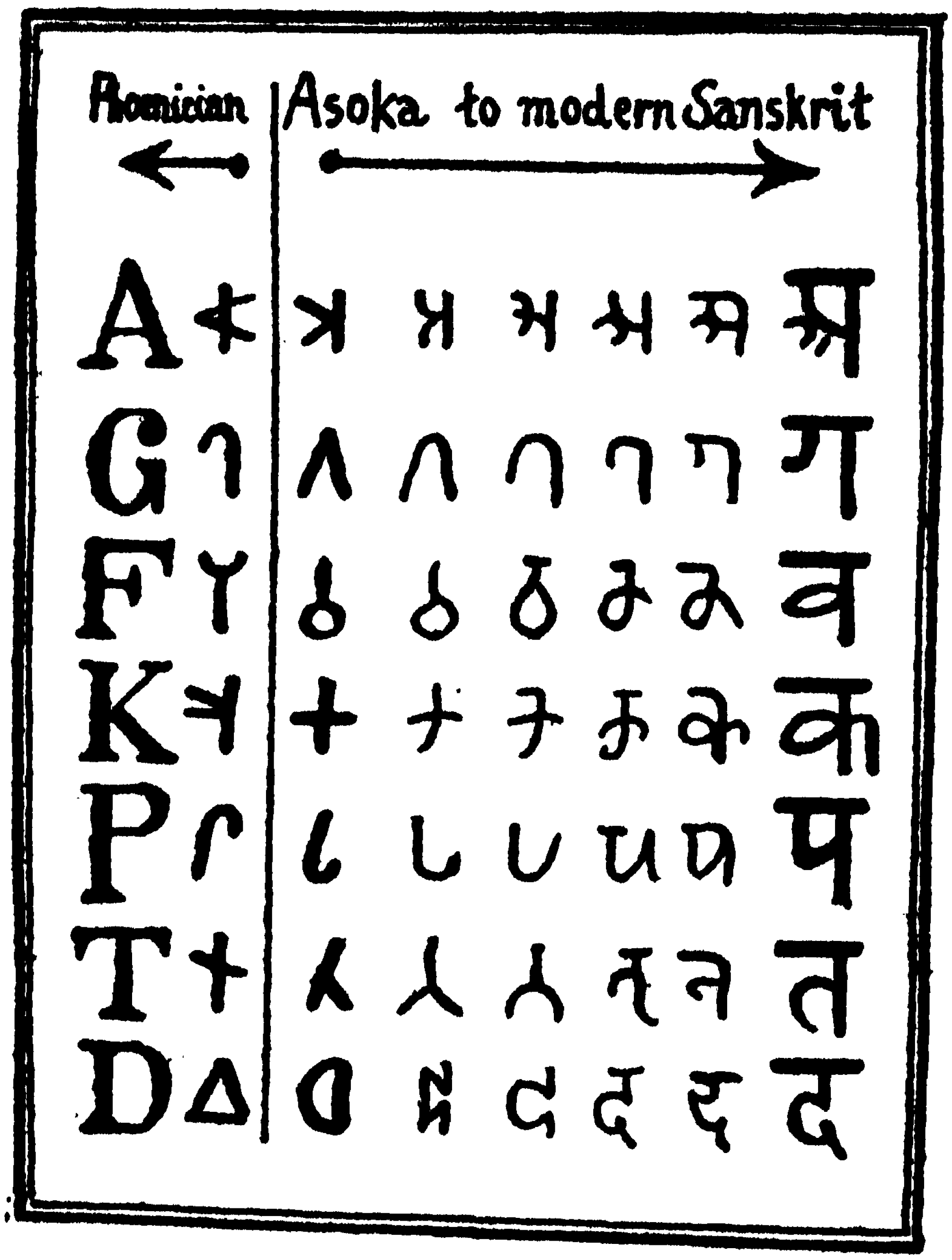
writing—the hieroglyphics or "sacred carvings" became restricted for use on stone and rock. We have now two styles of writing, the beautifully carved hieroglyphics and their abridged form, hieratic, which became more and more condensed and finally a mere outline of the original hieroglyphics.

As society progressed the "sacred" nature of writing became better understood by the masses, and the tradesman and soldier used a still more simplified form, the demotic (from the Greek *demotikos,* belonging to the people) derived from the hieratic (Greek *hieraticus,* belonging to the priest). Writing had now become a common art, and the first library was founded in Thebes around 1700 B. C. Here manuscripts were transcribed and the records and scrolls of deeds and acts kept.

A hundred years later, 1600 B. C., a summary of the medical knowledge, a medical encyclopedia, was collected in what is known as the Papyrus Ebers, named after its discoverer.

About the same time Moses led the Israelites to Canaan after he had learned the art of writing in Egypt. Whether the Hebrews in general became acquainted with writing in Egypt or whether the Egyptian emissaries and traders carried the demotic into Palestine, certain it is that the Semitic tribes, during this period, adopted and adapted the demotic writing to their own language.

In borrowing the demotic characters the Hebrews took unconsciously a stupendous forward step, for they selected but twenty-two characters from the multitude of Egyptian symbols. In Egypt the many hieroglyphic, hieratic and demotic characters prevented the general diffusion of the art of writing, which was made still more complex by a possible threefold use of one and the same hieroglyphic, as it could be used as ideogram (representing the object which it pictured), as a phonogram (representing the first syllable or vowel of the object), or as a determinative (representing the class to which the object belonged).

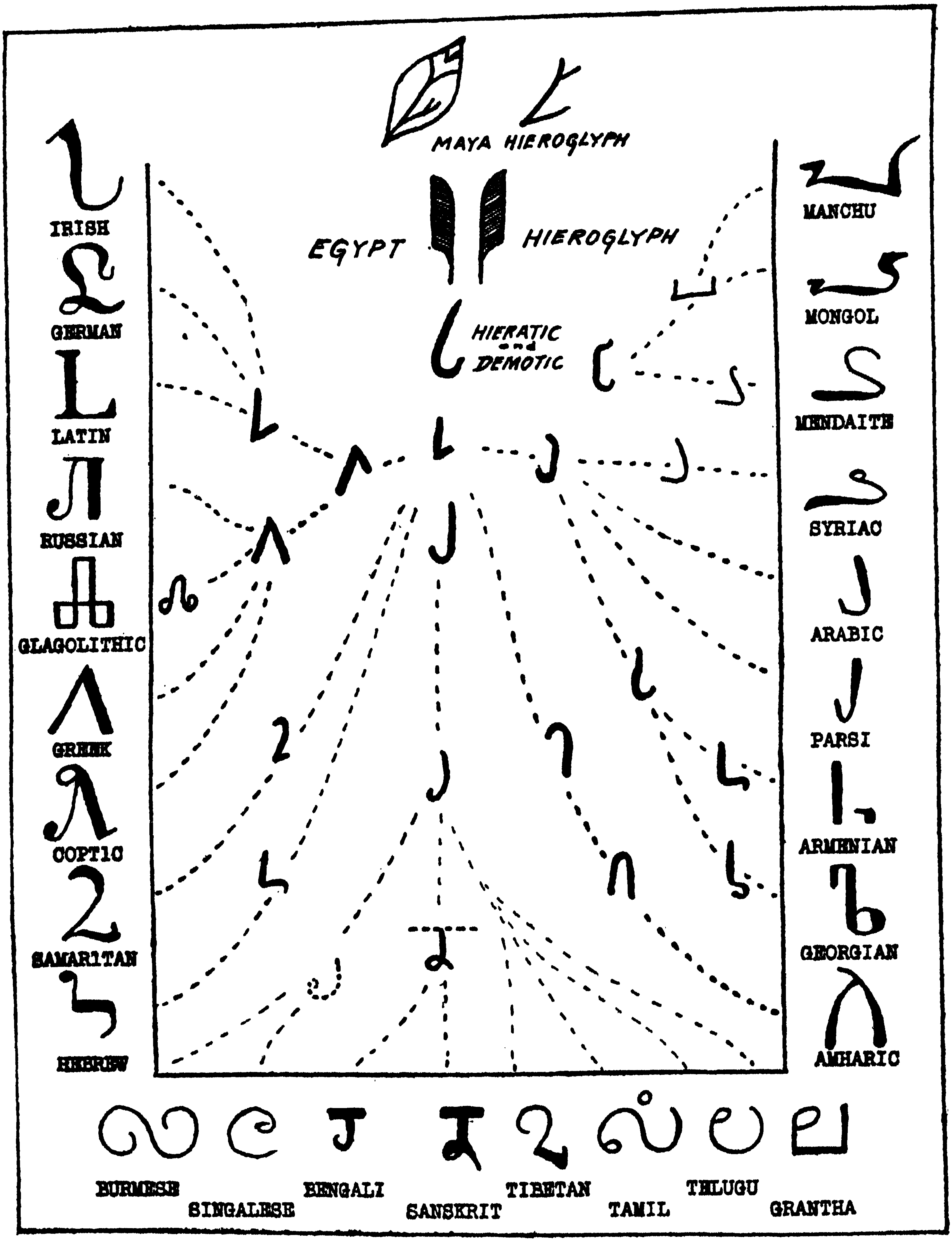


PHOENICIAN AND ASOKA GREW ON THE SAME STEM. FROM THE FIRST CAME MANY EUROPEAN ALPHABETS, FROM THE LATTER THE MANY INDIAN ALPHABETS. THE DEVELOPMENT OF SOME OF THE CHARACTERS TO SANSKRIT IS SHOWN ABOVE.

The alien race progressed further than the originating race, just as in historic times the Japanese reduced the 40,000 Chinese ideograms to about fifty syllable characters.

If the Hebrews had not borrowed their alphabetic characters from the demotic, the cuneiform writings developing in Assyria and Babylonia from picturegram to ideogram and phonogram would have become the ancestor of our alphabet.

The simplification of writing gave a great impetus to its use and we find the Semitic tribes and even the neighboring Babylonians using the characters on monuments, seals, gems, weights, coins and papyrus rolls. After five hundred



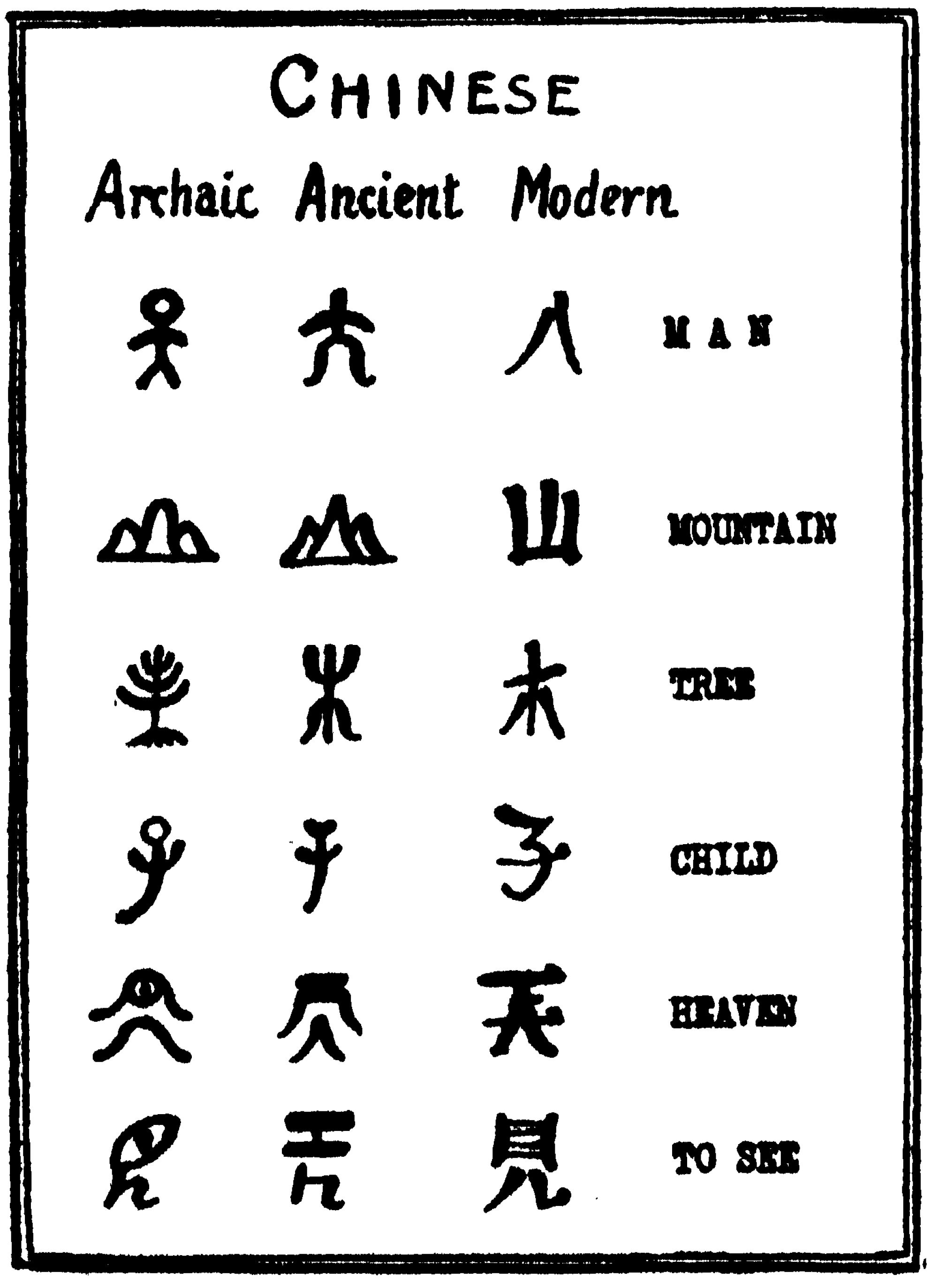
L

THE LETTER L HAS LITTLE CHANGED DURING THE CENTURIES. WE CAN RECOGNIZE IT IN THE SAMARITAN AND HEBREW, THE ARMENIAN, GEORGIAN, SANSKRIT AND THIBETAN. IT IS INVERTED IN GREEK, COPTIC, RUSSIAN, GLAGOLITHIC AND AMHARIC; REVERSED IN BENGALI, PARSI, ARABIC AND SYRIAC; AND SLIGHTLY ELABORATED IN MANCHU, MONGOL, GRANTHA, TELUGU AND TAMIL.

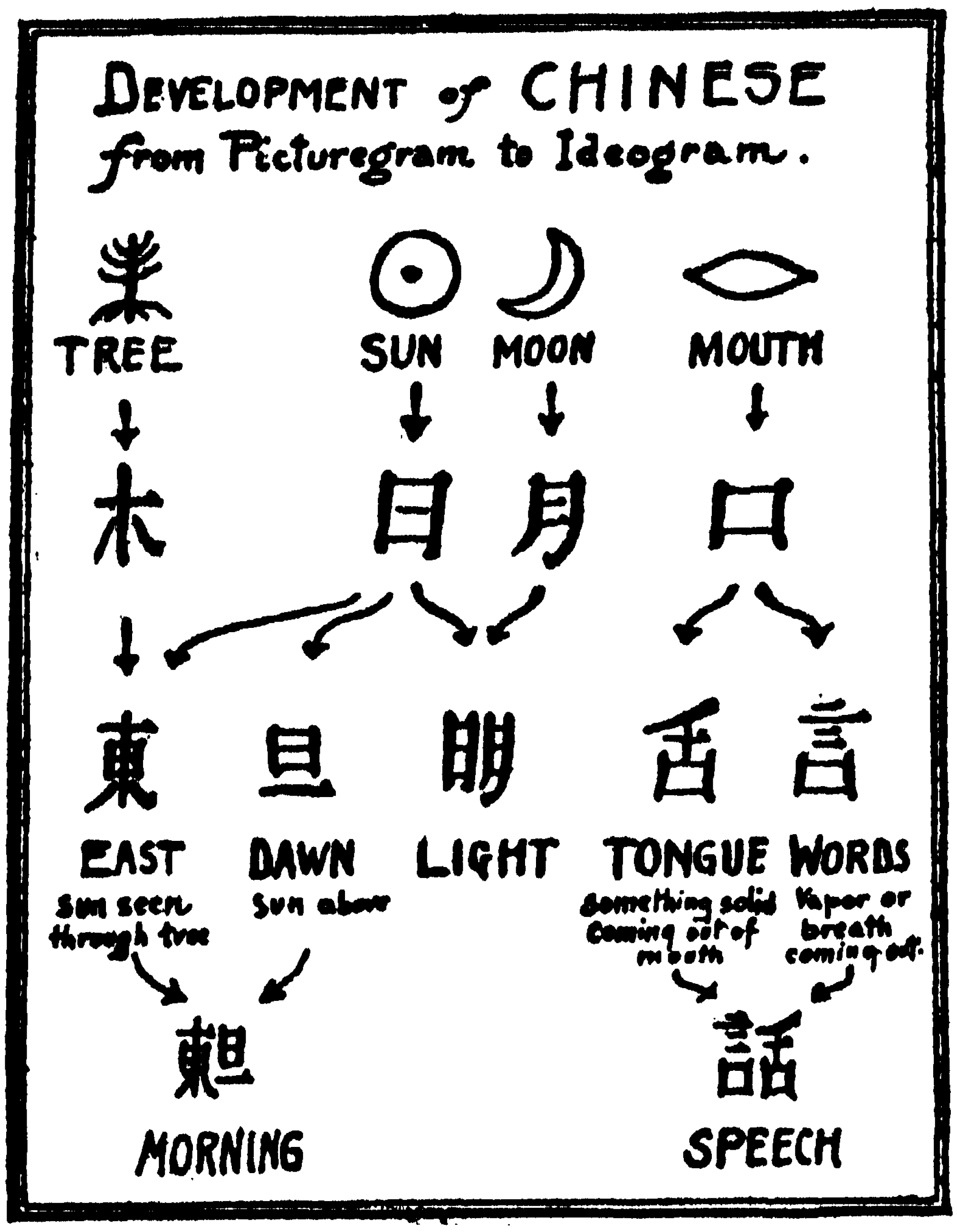
years, around 1000 B. C., fashion and local peculiarities of writing branched into two distinct alphabets, a northern and southern style of writing, which for convenience we will term the Phoenician and Sabaean alphabet. (See family tree.)

THE NORTH SEMITIC OR PHOENICIAN BRANCH

The Moabite stone is among the oldest Semitic inscriptions. This monument was erected around 900 B. C. and tells of the rebellion of Mesha, King of Moab, against the Hebrews. Mesha is indicated in the second Book of the Kings: "And Moab rebelled against Israel after the death of Ahab" (II King, I, 1). The characters of the inscription are crude and resemble those found as Sindjirlie (written around 800 B. C.) as well as the rock inscriptions discovered in the tunnel of the pool of Siloam, 700 B. C., which commemorates the completion of a water conduit to Jerusalem.



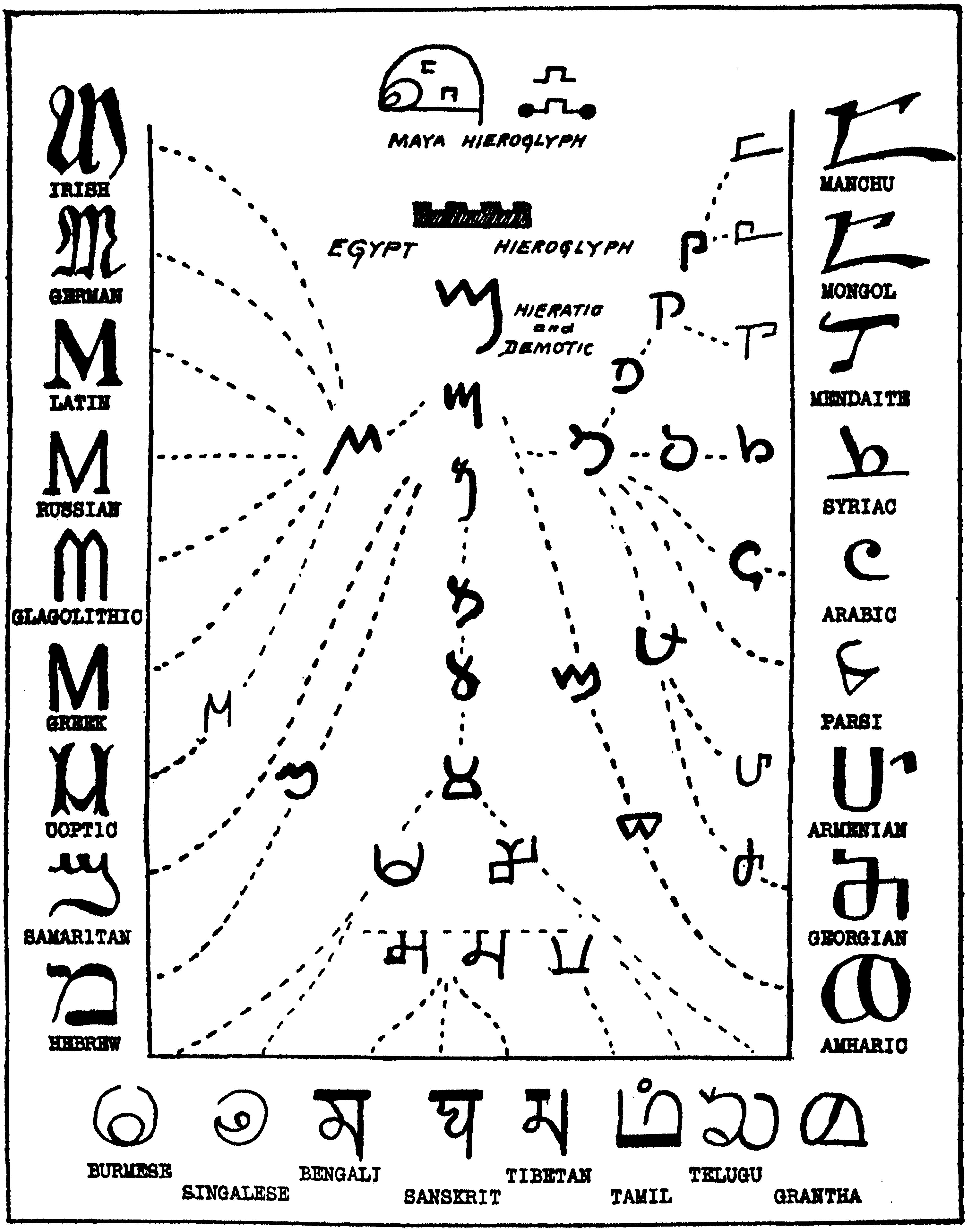
THE CHINESE CHARACTERS HAVE DEVELOPED FROM PICTURES, JUST LIKE THE HIEROGLYPHICS, CUNEIFORM, MAYA AND AZTEC WRITINGS. HOWEVER, THE CHINESE HAVE NOT PRODUCED A PHONETIC WRITING AND THE JAPANESE BORROWED ABOUT FIFTY CHARACTERS FOR A SYLLABLE WRITING.



THE CHINESE TRIED TO STEP FROM THE PICTUREGRAM TO THE IDEOGRAM, FROM THE CONCRETE TO THE ABSTRACT, BY COMBINING DIFFERENT CHARACTERS. THUS SUN AND MOON MEAN "LIGHT," THE SUN BEHIND A TREE "EAST"; EAST AND DAWN COMBINED MEAN "MORNING."

In the same period falls the rise and decline of the Phoenician city states Tyre and Sidon, who traded over the Mediterranean, reaching as far as Senegal in the south and Cornwall in the north. It was likewise the Homeric age, an indication of the awakening of the Greek tribes, and as the Phoenician traders frequently passed the Ionian and Dorian Islands, they caused there the ripple from which grew the alphabets of the Christian nations, the Cadmean branch on the Phoenician stem.

In the same period—900 to 600 B. C.—the Ethiopian usurpers caused the decline of Egyptian civilization which corresponded to the growth of the military power of Assyria and Babylonia



M

The mighty M is associated with fortifications, both in the Egyptian and Maya hieroglyphics. Its three strokes are discernible in Samaritan, Amharic, Georgian and Armenian. From a Hebrew-like character developed by shortening and prolonging of strokes the b-like Syriac, T-like Mendaite and c-like Arabic, Mongol and Manchu.

and caused the subjection of Jewish tribes. From these changes sprung the Samaritan and Hebrew or Rabbinic form of writing, the alphabets of the Jewish world: the Tyrian branch on the Phoenician stem.

Later came the rise and fall of other empires, the Median, Persian and Macedonian, and they likewise left their imprint in localized alphabets which became the ancestor of Turkish, Arabic, Syriac and other forms of writing of the Mohammedan world, the Sidonian branch on the Phoenician stem.

THE SOUTH SEMITIC OR SABAEAN STEM

Phoenicians were the traders of the north, Sabaeans the traders of the south, and as the characters borrowed from the demotic budded into the Phoenician stem, so the Demotic also grew into the Sabaean stem from which developed many modern alphabets. Phoenicia established the Semitic contact with the Mediterranean and Europe—Saba or Sheba was the Semitic contact point with Africa and India. The Sabaeans traded with the Ethiopians as far back as 1000 B. C. and with the trade came the art of writing and the keeping of records.

According to traditions the Abyssinians are the descendants of the Ethiopians and their royal family claims descendants from Menelik, the son of the Queen of Sheba. This Queen was an extensive traveler; she visited Solomon in Jerusalem and may have also resided in Abyssinia, thus bringing with her court and with traders the Sabaean writing to Ethiopia. Here the Sabaean developed into the Ethiopian branch, which survives in the modern Abyssinian or Amharic alphabet.

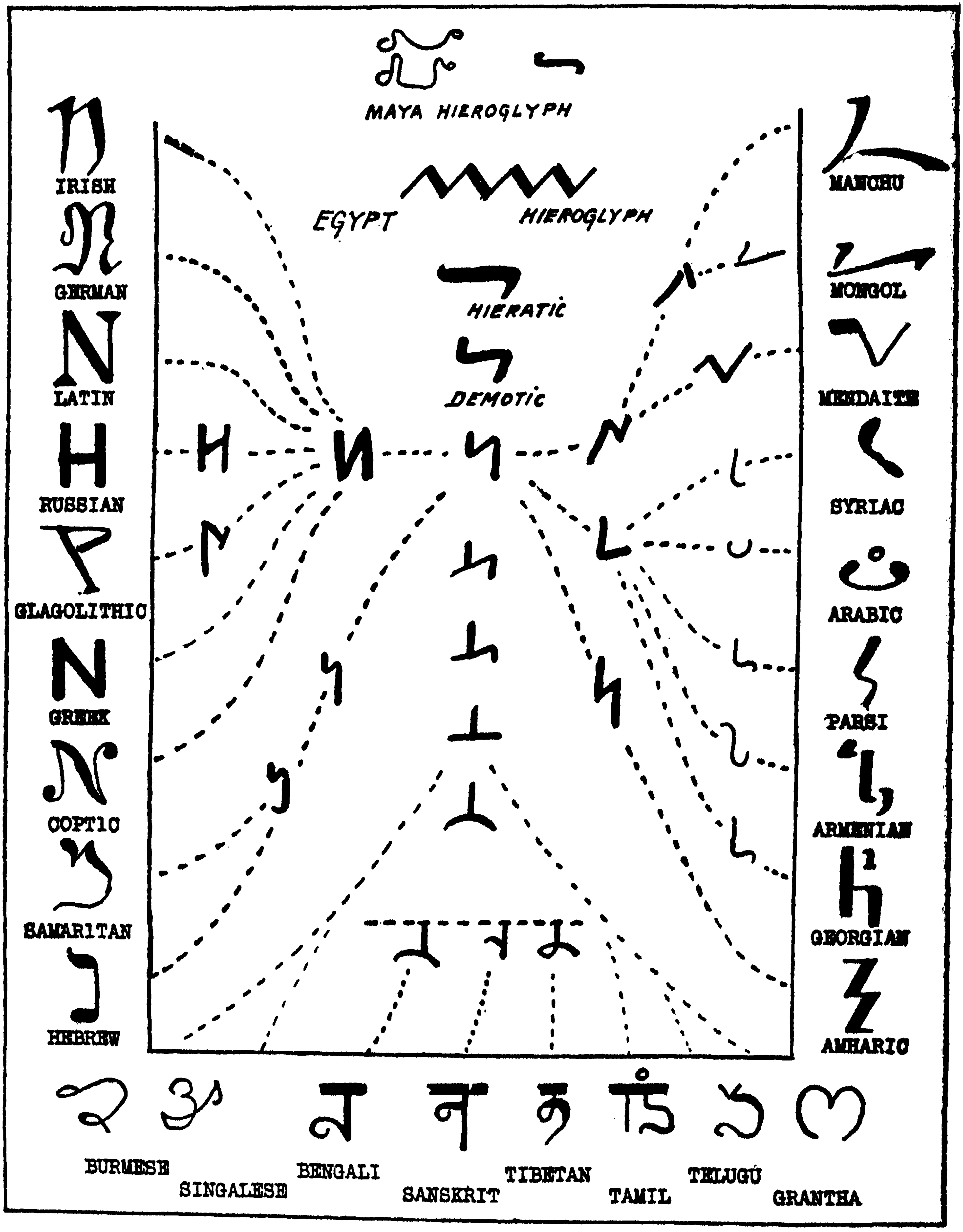
From the shores of India came the Dravidian sailors and with them Sabaean traders ventured to India and brought their way of writing, which became the "Brahmi lipi" and formed a crude embryo of the numerous alphabets of India, Siam and the East Indian islands. However, the Brahmi branch received later a new impetus and reinforcement from the Phoenician stem by the travels of Darius and Alexander the Great.

WHY THE ALPHABETIC CHARACTERS CHANGE

Before following the development of the different branches of alphabets in our family tree we must know the reasons why individual symbols are subject to change in appearance as well as in phonetic value. Why are they distorted, turned around and upside down, made more fanciful, rounded or squared?

One cause is the combination of materials used for writing, for the material written upon may be stone (monuments and caves), metal (coins, seals, weights or utensils), wooden tablets (records and letters), clay tablets, skins, papyrus or parchment, while the tool used for writing may be a chisel, stylus, knife, reed, brush, stick, feather or pen. By combining these two materials used for writing we find in general two forms—the monumental writing with straight lines, sharp corners and usually carefully executed by carving or engraving, and the cursive writing with curved lines, rounded corners and usually hastily painted or written.

Another cause is the succession in which the letters follow each other. At first the line of letters following each other was continuous and may be in the form of a spiral around a vase or stone pillar, or in zigzag form across the surface of a rock or piece of papyrus, first from right to left, then from left to right. This naturally produces an inverted form of letter, thus a W may become ⋞ or an ʍ . Even to-day we have not entirely overcome this inconventionality, for who has not seen a sign with the S reversed. Later scribes may select one or the other form of letter and standardize it by using it exclusively.



N

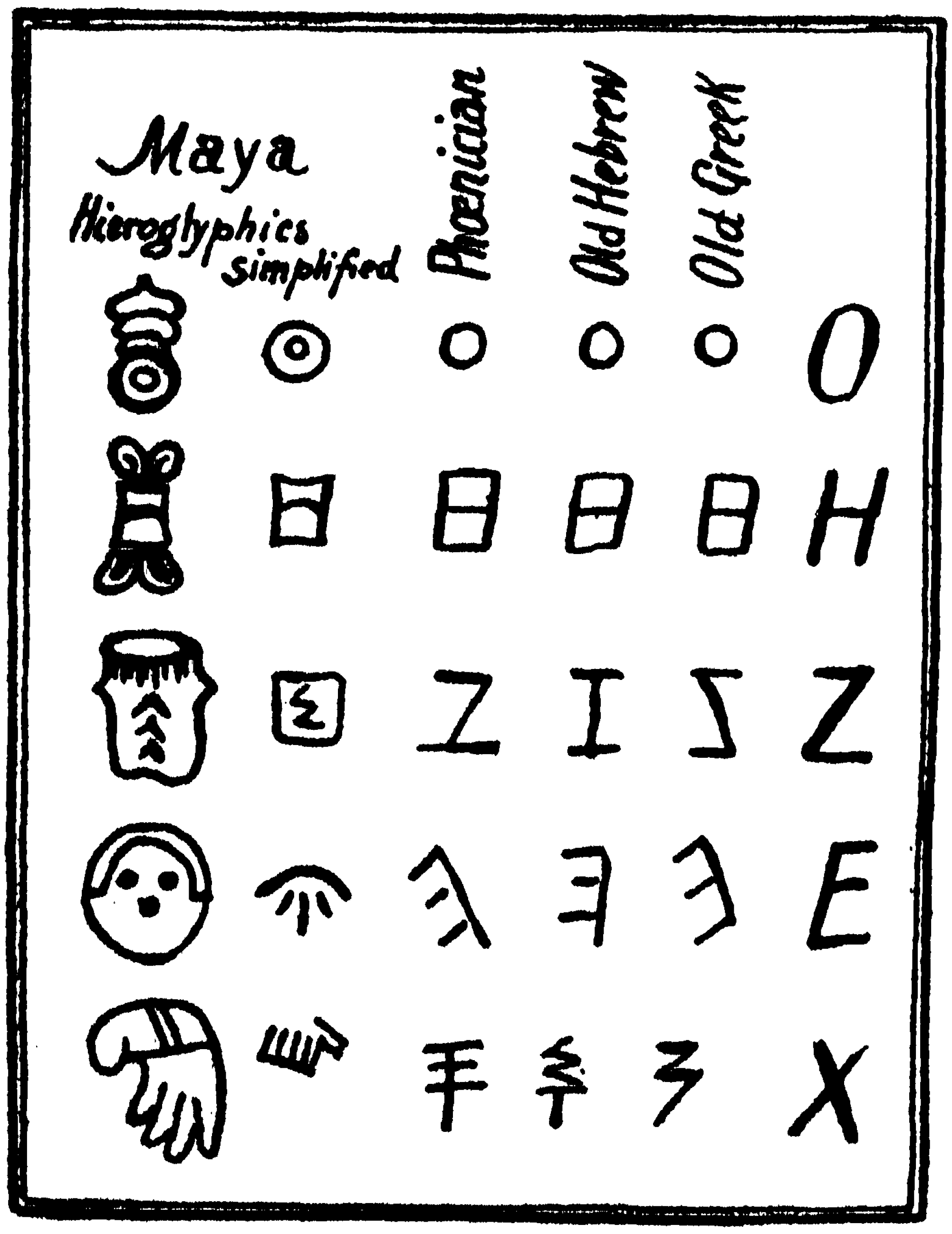
The strokes of N are old, for we see them in the simplified Maya hieroglyph as well as in the Egyptian hieroglyphs. It is preserved in the upper portion of Samaritan and Hebrew, in Mongol and Mendaite, in Parsi, Armenian and Amharic. By misplacement of the middle-stroke the H-like Russian character is formed, and by shortening of the end-stroke it yields the P-like Glagolithic.

Such examples are numerous in the history of our alphabetic characters.

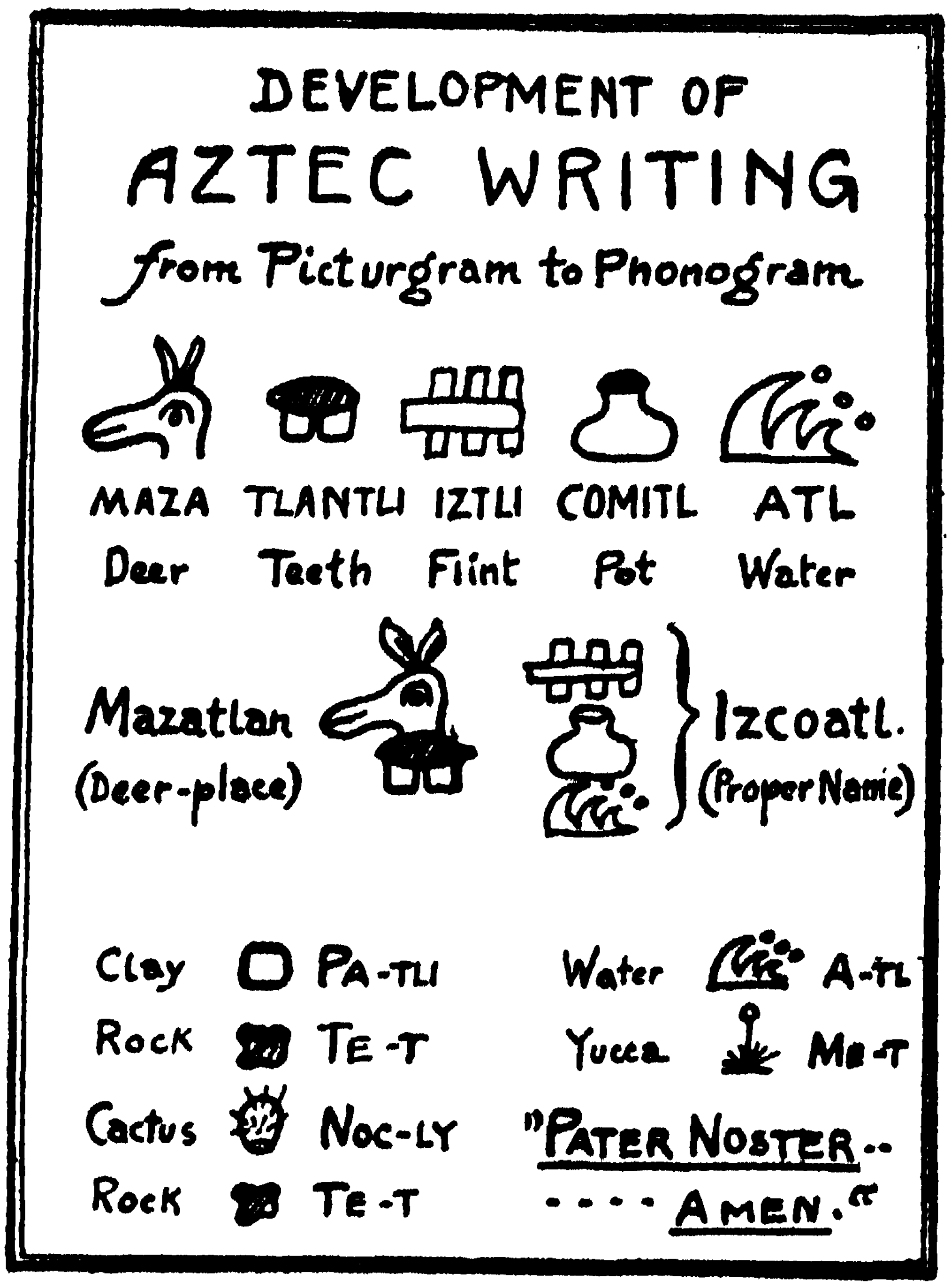
The direction in which the line is written becomes also conventionalized and uniform, thus (a) from left to right in the European alphabets, (b) from right to left in Hebrew, Turkish, Arabic and others, and (c) from above to below in Manchu and Mongol. This naturally influences the appearance of the letters.

Usually we write above the line; in India the habit was to write under the line and gradually the line became a part of the letter, even when a symbol stood alone. This gives the peculiar aspect to Sanskrit and Bengalese.

The fashion of using a more elaborate character at the beginning of a sentence or word began early in the Middle Ages and is the reason that we have capital and small letters. The capitals were generally selected from the so-called Uncials, a large, ornate and formal script in vogue during the sixth to eighth century among the monks of Central Europe. The small letters came from the Minuscele, a less formal and cursive style of writing developed by the monks in copying and rewriting manuscripts. With the advent of printing more changes came so that we have at least four characters for each letter, type and script, capitals and small letters.



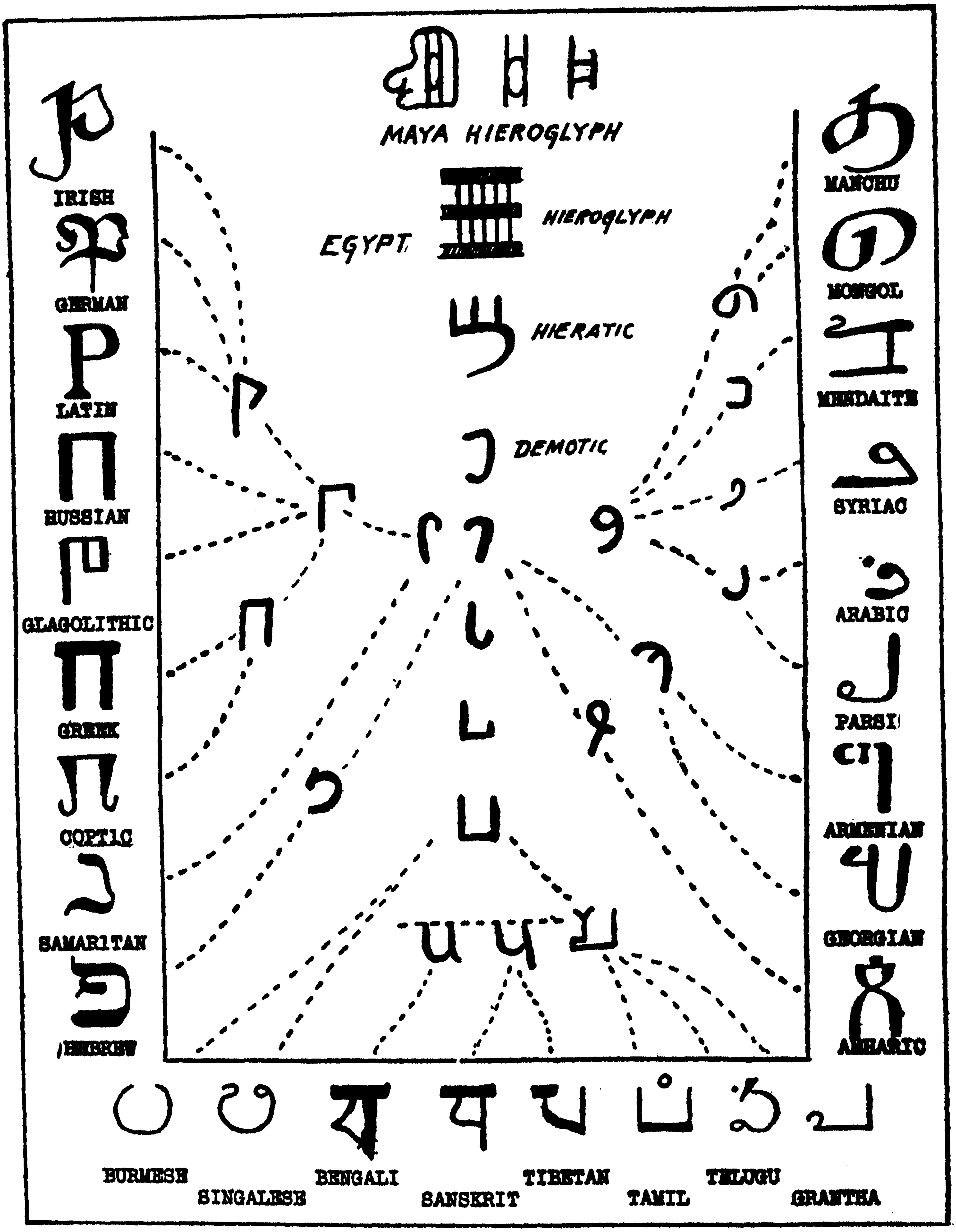
There are many striking resemblances between the simplified form of the Maya hieroglyphics and the demotic or Phoenician derived from Egyptian hieroglyphics. This fact, among others, has led to the assumption that there existed a common origin of both, the mysterious Atlantis.



The old Mexicans developed a picture writing which grew into a phonetic writing. When the Spanish conquerors came and the Jesuits converted many of the natives to Christianity, this writing was used for the Lord's Prayer as shown above: Pa-Te Noc-Te . . . A-Me, the R being unknown to the natives.

The Christian Alphabets developing from the Cadmean Branch

We have seen that the Ionian Islands were the contact point of east and west, Greece and Asia Minor. There it was



P

THE P DEVELOPED FROM A HOOK WHICH BECAME SQUARE IN RUSSIAN, GLAGOLITHIC, GREEK AND COPTIC; TURNED UPSIDE-DOWN IN THE INDIAN ALPHABETS; LYING ON ITS SIDE IN SAMARITAN, HEBREW, ARABIC AND SYRIAC; AND TURNED AGAIN IN MONGOL AND MANCHU. THE SIMPLIFIED MAYA HIEROGLYPH RESEMBLES LIKEWISE A P.

that the primitive Hellenic tribes were stimulated to thought by comparison of their ideas with those of the seafaring Phoenicians. Accordingly the oldest Hellenic inscriptions are found on the islands, and among them are those of Thera, which closely resemble Phoenician.

Cadmus, the legendary hero, is merely the personification of the Phoenician influence, and the Greeks adopted with about sixteen characters the Semitic names. Thus, aleph becomes alpha, betel changes to beta, gimmel to gamma, and so on, and even to-day we speak of the ABC as the "alpha-bet."

From the archaic Hellenic forms of writing—the Ionic, Doric and Attic, there blossomed forth the modern Greek, the modern Slavic alphabets, modern English, German and Irish.

Through migrations and travels of the primitive European tribes the archaic Greek writing filtered to the northern barbarians who guarded them as sacred symbols. We find them in the Runes of the North from which came the now extinct alphabets of the Wendes, Goths and Alemans. From the Alemanic grow the Anglo-Saxon and Meso-Gothic, and from the first the modern Irish is derived. In the German and Old English characters likewise are found the influences of these northern alphabets.

The art of writing traveled not only northward, but also westward, for Greek colonists settled in Sicily and Italy and brought the spark of knowledge which gave rise to the Etruscan and Latin alphabets, which ultimately developed into the characters in which this article is written and printed.

Much later another series of alphabets evolved from the Hellenic family. In 863 A. D. Cyrill, the founder of the Eastern Christian Church, came from Constantinople to Monrovia to convert the Slavic tribes to Christianity. At that time the Greek Uncials or large letters were used by the monks and this form of writing was adapted by Cyrill to record the Slavic language. Thus was born Cyrillic, the prototype of Russian Ukrainian, Servian and Bulgarian. Later, when the minuscele, the cursive or small Greek letters, were in vogue, a similar adaptation was made to fit the Slavic tongue, and this alphabet, the Glagolithic, survived until the seventeenth century in the religious books of the Croats, and is in its modern form the Dalmatian and Albanian script.

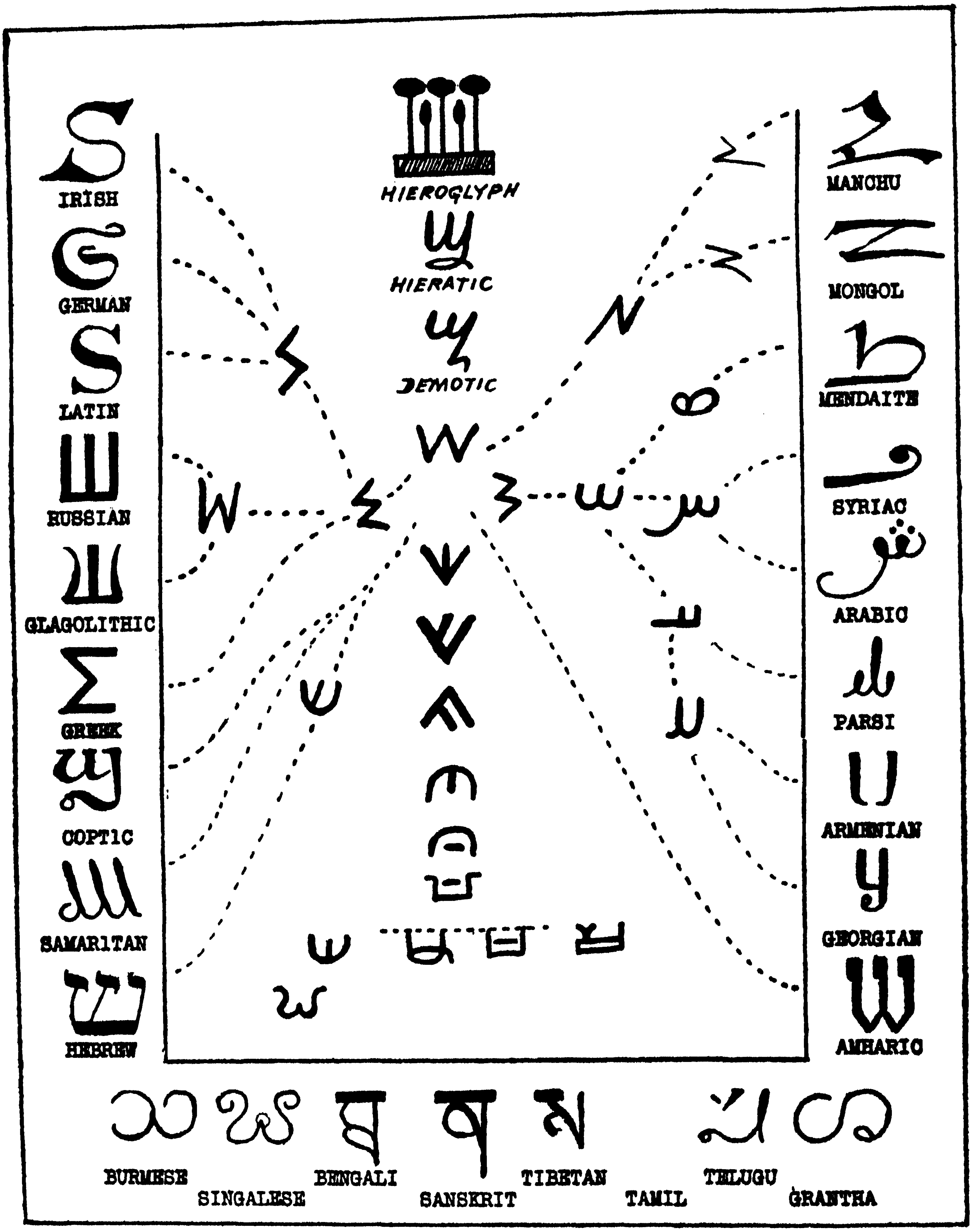
THE JEWISH ALPHABETS DEVELOPING THE TYRIAN BRANCH

We turn back again to the Israelites under the Kings and the time of the destruction of Jerusalem and the Babylonian captivity. Previously the Israelites had used the primitive form of writing borrowed from the demotic, but now as they drifted back from exile the Aramaic characters had become popular in Palestine and, indicative of the new start being made, were accepted. Thus the Book of Daniel, 160 B. C., is typical of this form of writing, and these characters became the pattern for the Herodean style used during the time of Christ. Later, about 300 A. D., the characters were "squared" and from the square Hebrew grew the present-day Rabbinic characters.

The Samaritans, however, stuck to the old form of writing which had been used in 580 B. C. before the Babylonian captivity, and from this sprung the modern Samaritan used to this day by a small religious sect in Palestine.

THE MOHAMMEDAN ALPHABETS DEVELOPING FROM THE SIDONIAN BRANCH

While the Cadmean branch became associated with the Christian religion and spread over the world, and the Tyrian branch diffused through the world with the Jewish people, so the Sidonian branch travelled far and wide in the wake of Mohammedanism. But long before it became a carrier of religion it played an important part in civilization.



S

S is associated with the "sh" of the rushes of Egypt, the hieroglyph of which became conventionalized to a W-like character, still preserved in Russian, Glagolithic, Coptic, Samaritan, Hebrew, Burmese, Singalese, Amharic, Parsi and Arabic. It is laid on its side in the Greek sigma, lost a stroke and became rounded in the Latin and Irish S, turned through ninety degrees and produced the Z-like Mongol and Manchu characters.

Around 500 B. C. Darius, "a Persian, son of a Persian, an Aryan, king of the Aryans," was a devout follower of Zoroaster and extended the Persian empire from the Black Sea to the Indus, from Thrace to the Punjab. But coming into India he found the Brahmi lipi, introduced earlier by the Sabaeans, and he enforced the use of Kharosti, an Aramaic form of writing which was the fashion among the Persian satraps in all their colonies.

Thus Darius, and later Alexander, created at the crossroads of the Punjab another contact point from which arose another center of civilization and learning.

The Aramaic was principally connected with the Avesta, the book still used by the Parsees, and of which the Zend is the translation or transcription into a modern form of Pahlavi, from which developed the Iranian family of alphabets—modern Persian, Hindustani and Pushti.

A later development of the Aramaic characters is the Hauranitic family, which is associated with the rise of the Arabs and Saracens. Around 500 A. D. we find two forms of old Arabic characters, namely, Nashki or cursive writing, used on papyrus and parchment, and Kufic or monumental writing, used on rock inscriptions, coins and seals. From the first comes the modern Turkish and Arabic, from the later the Syriac.

Nestorian, a patriarch of Constantinople, founded in 435 A. D. a Christian sect, and his missionaries created a wave of Christianity in Central Asia. Their form of writing was the Estrangelo, literally the "writings of the gospel," which still survives in Mendaite, a small sect of Christians in Armenia. The Nestorian missionaries laid also the foundation for the alphabets of the Turkomans and Mongols; Uigur, Manchu, Mongol and Korean. In the transition of Estrangelo to these Asiatic alphabets we witness an interesting turning of the letters, indicated in the illustrations by a dotted line. Instead of writing from right to left, the letters had to be written downward in Chinese style. At first the paper was probably turned through 90°, but in time the characters became modified to suit the new direction and style of writing.

Another Christian missionary, Bishop Mesrobian, was active around 1000 A. D. in what is to-day Armenia, where he introduced an alphabet which "he conceived in a dream," but which is really a mixture of Persian or Iranian with Nashki and Greek. This alphabet developed into the modern Armenian, and in an inverted form into the modern Georgian.

THE COPTIC BRANCH OF THE SABAEAN STEM

One of the most interesting alphabets is the Coptic, which has been preserved up to the present day in the least changed form. Many of its characters still resemble closely the ancient demotic characters derived from the Egyptian hieroglyphics. This alphabet is used appropriately by the Copts, the native Egyptians, which have remained Christian in spite of Saracen invasions and have kept their traditions, language and writings in spite of the many vicissitudes.

THE ETHIOPIAN BRANCH OF THE SABAEAN STEM

Just as the Copts have a direct descent from the old Egyptians, so the Abyssinians are descended from the Ethiopians. The courtiers of the Queen of Sheba had brought the first primitive alphabet, and in 100 B. C. the semibarbaric Ethiopians revived their art of writing by borrowing the Meroitic alphabet from the Demotic. This grew into the modern Amharic.

THE BUDDHIST ALPHABETS DEVELOPING FROM THE BRAHMI BRANCH

This large branch on the Sabaean stem is not restricted to Buddhism and India, but includes other religions and countries, and presents, in its history, a mirror of the complicated and intricately woven history of India and Southern Asia. Two races have always struggled in India, the dark-skinned natives—the Dravidians—and the light-skinned invaders—the Aryans. The battleground was the Punjab at the foot of the Himalayas and at the narrow entrance gate to the great peninsula.

Wave after wave of Aryans came through the northwestern passes and invaded the plains, driving the natives and previous settlers before them into the great peninsula. With each invasion came new blood and a new stimulus to poet and philosopher. Darius had brought the Avesta, Buddha and Mahavira had preached in Magadha, and now came between 264 and 227 B. C. the great Asoka, King of Magadha, who did for Buddhism what Constantine did later for Christianity. Asoka spread the principles of his faith far and wide by many edicts, which are still preserved on stone pillars, on rocks and in cave-inscriptions. All these inscriptions are still a silent witness to the tolerance of Asoka, for they bear the older Brahmi lipi (written from the left to the right) and the newer Kharosti (written from right to left). From these two alphabets developed the many scripts used in India, Ceylon, Burma, Siam and the Malay Archipelago.

There are one hundred and forty-seven vernaculars in India alone, and the alphabets had to be adapted to each particular one. Thus the characters may be found to change their sound when they are traced from one language to the other, but nearly always they modify their shape according to the decorative tendency of the tribe or sect. They may become circles or squared little blocks, simple or ornate with scrolls and curves.

Brahmi was the older, Kharosti the intruding alphabet; hence the first one was held always in greater esteem and it usually furnished the prototype of the Indian alphabets. The development can be followed through the cave inscriptions made during the Kushan Dynasty, the rulers which were contemporary with Christ—followed by the Gupta Dynasty three centuries later, and so on through succeeding dynasties. The simplest grouping of the Indian alphabets is in accordance to their geographical distribution.

The Devanagari family is found in Northern India, where it branches out into the Pali alphabets used for writing the monosyllabic languages in countries as widely separated as Thibet and Siam; the Punjabi alphabets, to which belongs Bengalese, Sindhi and Ghurmuki, and finally the "Sanskrit" alphabets. Sanskrit is a language and as such is written in many different alphabets, including the English, and what we commonly call "Sanskrit" is the Nagari alphabet or "town script," which is generally understood by all educated classes of India and is used in Europe and America for printing the Sanskrit language.

The Nerbuddha or Transgangese family of alphabet has its range in Central India, Ceylon, Eastern India and Burma, and it branches into the Laocian, Tamil, Telugu, Singalese and Burmanese alphabets.

Finally, the Kari or Oceanic family holds its sway over the Mayalan Islands —Java, Sumatra, Borneo, Celebes and even the Philippine Islands.

THE FUTURE OF THE ALPHABET

In brief such has been the history of the alphabets. By a slow and tortuous path man has climbed toward the goal of a phonetic alphabet. Nowhere has he achieved this goal, although by a miraculous fate the same raw materials were given to many races and nations. But as progress is bound to continue we shall by and by overcome the inherent inertia and evolve a scientific alphabet—a single character for each sound, and a single sound for each character.

SPIRITUAL VALUES IN SCIENCE

By Professor VICTOR E. LEVINE
CREIGHTON UNIVERSITY, OMAHA, NEBRASKA

> Blessings on Science! When the earth seem'd old,
> When Faith grew doting, and the Reason cold,
> 'Twas She discovered the world was young,
> And taught a language to its lisping tongue;
> 'Twas She discovered a future to its view,
> And made old knowledge pale before the new.
> —*Charles Mackay*

MODERN civilization is the resultant of two forces—the old, the inherited spirituality of the past blended with the new, the process of pure science and its applications. A hasty survey of the history of science reveals the remarkable fact that the latter is but of recent potency. The second half of the last century showed greater strides in scientific achievement than all the other centuries put together. Judging pure science from the standpoint of its applications, we certainly must marvel at the great progress made in this field. It is in but recent times that the scientific progress of the world has brought forth the steamship, the locomotive, the automobile and the aeroplane; the typewriter and the linotype; the mowing machine and the harvester; lithography, color photography and moving pictures; the motor, the dynamo and the electric light; the telegraph, the telephone, the phonograph and the radio. In fact, so thick and fast do new discoveries and inventions come upon us that we accept the most interesting and the most ingenious with a degree of calm bordering on indifference.

Science is continually increasing the comfort and happiness of the human race. It has relieved us from the task of pitting our mere physical strength against the forces of nature. It has magnified through the microscope and the telescope man's vision and has revealed to him undreamt-of worlds. Through implements and machinery it has miraculously augmented his physical capacities. Annihilating space, it has made possible the exchange of goods and ideas, and has thus helped to establish a tie of interdependence and a bond of sympathy among the peoples of the earth. It has through antitoxins and disinfectants saved many human lives. It has relieved pain. Well may S. Weir Mitchell sing to the blessings of anesthesia, in his poem, "The Birth and Death of Pain":

> Whatever triumphs still shall hold the mind,
> Whatever gifts shall yet enrich mankind,
> Ah! here, no hour shall strike through all the years,
> No hour so sweet as when hope, doubt, and fears,
> Mid deepening silence watched one eager brain
> With God-like will decree the Death of Pain.

Much has been said and written upon the material aspects of science. Surprisingly little has been the emphasis placed upon its spiritual values. In reality the chief usefulness of science lies not in the material advantages it offers the human race, but in the spiritual enrichment with which it endows the individual pursuer in particular and mankind at large when it makes righteous employment of its applications, inventions and discoveries. What science has to impart to the higher spirit of man we shall presently discuss.

Science sheds brilliant rays of hope upon the future. In the last hundred years tremendous strides have been made through the modern development of science in the direction of controlling the physical forces for man's economic needs. The age-old problem of ministering to man's spiritual wants will then have ample time and opportunity to make itself felt as never before in the history of mankind. Present civilization, the outcome of scientific achievement, will then give right of way to future humanization. Life will cease to be one long fever and yearning for possession and conquest, for sensation and excitement. The life of to-day, "a Niagara force without direction, a noise without significance, a speed without accomplishment," will be superseded by the life of the future, which will be alert and not inert, spiritual and not mechanical, religious and not political, mindful of peace and not of power. No longer will there be the breathless rush with which

> We pass and nod and hurry by,
> And never once possess our soul
> Before we die.

As one of the three great tasks that occupy human life Dr. Felix Adler gives the building of our finite world, which, he believes, is accomplished by means of science and its adjuncts. The building of the finite world is not the highest function of science. Its supreme goal is to link nature to man, the finite with the infinite, the self with the non-self; to emphasize the relation of one to all, and to show the unbroken continuity of the inner with the outer world. The current of life which runs through our veins night and day flows through the stem and the leaf and the flower, the rivulet and the mighty ocean. The song of the world and the "music of the spheres" both give expression to the divine harmony. The beauty of nature and the noblest work of man are but different notes necessary to give completeness to the divine symphony.

What is the end of man? It is the realization of the infinite in him. The finite represents the road by way of which man is to rise to spiritual power. The struggle of life is but concrete representation of the tension which accompanies the attempt to pass beyond the finite. Only through nature can the human spirit attain realization. The earth and its forces are not merely physical phenomena to be looted and then left aside; they are essential to the attainment of the ideal of perfection, just as every note is necessary for the attainment of musical harmony. The true scientist sees in natural facts not merely foundation stones for hypotheses, theories and laws, or dumb-bells for mental exercise, but the universal pattern, the spiritual significance. The scientist travels along the path of the finite in order to arrive at and pass through the gates of the infinite.

The true scientist has the poet's attitude toward life. Since poetry can not fulfil its purpose unless it embodies philosophic vision, unless it offers an interpretation of life and gives a fuller view of reality, the scientist must also possess the philosophic attitude toward life. The beauty and order of the world are recreated alike in the vision of the poet and of the artist, in the mind of the philosopher, and in the laws formulated by the scientist. The aim of the poet, of the artist, of the scientist, and of the philosopher is to reveal life within things, the soul within matter; to mirror life not at its surface, but at its deepest roots. The poet and the artist worship God as the spirit of beauty; the philosopher and the scientist pay their homage to God as the ideal of truth. Philosophy is the temple of truth; poetry and art, the shrine of beauty; science, the holy law. Science and philosophy seek truth; poetry and art seek beauty. There is no opposition between the two, for beauty is truth and truth is beauty. Goethe expresses this fusion in lines translated by Carlyle:

> As all Nature's myriad changes still one changeless Power proclaim

So through Thought's wide kingdom ranges
one vast Meaning e'er the same;
This is truth—Eternal Reason—that in beauty
takes its dress,
And serene, through time and season, stands
complete in righteousness.

Starting from different points philosophy and science and poetry travel toward the same destination. They approach reality from different angles. The philosopher and the scientist grasp the synthesis which gathers together all the aspects of the universe. The poet and the artist aim at catching the vision which sees things of beauty of the world as a whole. The goal of each is to formulate a theory of the universe.

The human soul to rise to heights of poetic rapture or scientific vision should become attuned to the soul of things beyond. The inner and outer self must melt into one sweet harmony, for poetry and science echo the melody of the universe. Poetry, or art, or science, or philosophy can be achieved only by a mind at rest, at peace with itself. Poetry, art, science, philosophy, express rhythm of life and harmony of soul. That individual can not be a great poet, a great artist, a great scientist, or a great philosopher, who is ill at ease with the world, who believes it given up for lost, who sees an irreconcilable breach between evil and good, between inferiority and superiority, who looks upon an ideal as something beyond the realm of accomplishment. The poet, the artist, the scientist, the philosopher must have a love of nature and creation and must have faith in the soul of the universe. He must regard it with disinterested affection, not only for the joy it gives, but also for the concept it develops of a higher spiritual life.

The true poet, the true artist, the true scientist, the true philosopher must hear harmony in the Babel of so-called nature and must see uniformity in manifold and seemingly perplexing diversity. The poet and the artist are convinced that the end of all is peace and atonement, and not discord and despair. The scientist is just as strongly convinced that all discord is harmony not understood. Philosophy and science make the world rational and orderly; poetry and art make the world beautiful and harmonious. Disorder and irrationality, philosophy and science can not accept. Discord and ugliness, poetry and art can not tolerate. In poetry and art, philosophy lives; in science, poetry and art, philosophy takes on flesh and blood.

Since science is tinged with poetic vision and philosophic insight, it helps to reveal and intensify the spiritual side of man. It seeks beauty and truth in the manifestations of nature and introduces that philosophical spirit, that spirit of discernment which submits everything to reasoning, condemns ignorance, destroys error, and dispels prejudice. It thus raises the intellectual level and moral sense, and with these strengthened, the ideal of divinity takes full possession of the soul. The poetic genius of William Wordsworth gives most adequate expression to the wholesome inspiration of communion with nature:

For I have learned
To look on Nature, not as in the hour
Of thoughtless youth; but hearing oftentimes
The still, sad music of humanity,
Nor harsh nor grating, though of ample power
To chasten and subdue. And I have felt
A presence that disturbs me with the joy
Of elevated thoughts; a sense sublime
Of something far more deeply interfused,
Whose dwelling is the light of setting suns,
And the round ocean, and the living air,
And the blue sky, and in the mind of man;
A motion and a spirit, that impels
All thinking things, all objects of all thought,
And rolls through all things.

And the poet continues to pour forth the joyous recognition of the debt he owes to the uplifting influence of Nature:

> Therefore am I still
> A lover of the meadows and the woods,
> And mountains; and of all that we behold
> From the green earth; of all the mighty world,
> Of eye, and ear,—both what they half create,
> And what perceive; well pleased to recognize
> In nature and the language of the sense,
> The anchor of my purest thoughts, the nurse,
> The guide, the guardian of my heart, and soul
> Of all my moral being.

Nor is the poet alone capable of richness of spiritual vision. Let us hear from a geologist, John C. Merriam, who set forth in the January issue of the Scientific Monthly, 1921, in the following words:

> One does not expect a geologist to state his views on philosophy in phrases aiming at the deeper human understanding, and yet there seems reason for feeling that the wider outlook of science in all of its aspects lifts us up to the identical viewpoint from which the philosopher and the poet obtain their comprehensive vision. Unlike the philosopher we do not reach backward to explain the origin or forward to interpret the ultimate purpose of Nature; nor can we, like the poet, picture in words with fullness of meaning the view which opens to us, but the type of landscape spread before us and the training of the eye which sees it give to our picture a measure of reality which its stupendous magnitude does not lessen. Of all favored men the geologist and the paleontologist see the panorama of the past unrolled in clearest reality. To them the life record is not written in doubtful hieroglyphics and symbols. It represents the imprints of living feet that have never ceased to advance in unbroken procession over a trail that winds upwards through the ages. From one glimpse at footprints on the sands of time, a poet in the person of Longfellow gave to all generations a Psalm of Life, which has found response in the ever widening circle of human hearts. Pointing in the same direction, but of infinitely deeper meaning than the lines of the poet, is the reality of the story, the sermon, the poem which the geologist sees, which must of necessity reach its recognition through his eyes and its expression through his voice.

The true scientist has the religious attitude towards life. Whenever we find a devotion which makes the finite seem as nothing and some reality to which it attaches itself as all, we have the essentially religious attitude. All such surrenders to unselfish ideals are dedications to higher causes. They abound in the fragrance of the beautiful and carry the semblance of the eternal. A high ideal sets the self free and delivers one from selfishness. Even the common, ordinary, everyday experiences would take us to heaven could we whole-heartedly surrender ourselves to them. The work-a-day world, its things and its events cause trouble of mind and pain of spirit, when we employ them for our own sensation and enjoyment, instead of making use of them for spiritual and unselfish ends. Man's happiness is attained not through getting but through giving himself up to what is greater than himself. In such giving the characteristic traits of religion are ever present.

Selfishness is the unpardonable sin of man. It is his failure to be true to himself. It is the rejection of the divine in him. It is the root-cause of evil and its long train of votaries. It is the fog which obscures his vision and hides his true being. It is the mask that conceals the divine glow in his face. Devotion to an end beyond himself leads to the larger life. If human nature is so limited that absorption into a larger end is impossible, then the fate of man is indeed very pitiable!

The pursuit of science calls forth the spirit of unselfish service. Not only religious movements and movements for greater political freedom, but science also can claim its martyrs. Into the real spirit of science one can not enter without knowing of the failures and successes, of the hardships, trials and tribulations, of the self-sacrifice and self-denial, of the enthusiasm and perseverance of the men who slowly, laboriously, untiringly have added to the ever-expanding storehouse of scientific fact and scientific theory.

Man is distinguished from the other species in creation by his constant conscious endeavor to go beyond his own physical limitations of self and nature. He has succeeded in removing many of the barriers of an environment to which he no longer reacts passively. He comes to a world which has in the past been created by the will and power of his predecessors. Man is a dynamic force. Freedom of growth should characterize his activities. Freedom of growth implies freedom for creative growth. And when he fails to do his share of creative work, he sins against the self, the infinite, the eternal in him. His salvation lies in forging beyond the circumference of the circle in which he feels himself the self-center. To go beyond this circumscribed boundary, to realize the infinite, he must learn to surrender cheerfully the material, the finite.

This giving up of finite interests dear to man at first involves suffering, hazard, hardship. The steep path to realization is lined with thorns. The infinite is attained only by the brave, the sincere, the back-boned and not the wish-boned, the stout-hearted, the vision-souled. The worth-while in life comes through effort. The worth-while is like oil in the seed. We must apply pressure to obtain the oil; churn milk to have butter; dig the ground to have water. Till the goal is obtained we meet with unforeseen dangers and unavoidable risks. We have to fight with the finite not merely physical wars but spiritual wars as well. All progress comes as a result of giving up and casting off the finite. The young mother, possessed of charms, grace and beauty, throws them all away for the higher pleasure of beholding her first-born. It does not matter if this pleasure comes in anguish at the cost of her charms and even at the peril of her life. The fragrant and bright-colored flower dies for the sake of the fruit, the fruit for the sake of the seed, the seed for the sake of the plant. Struggle and sacrifice are the world's supreme blessings. It is the travail accompanying the birth of a higher soul. It is the attempt of the infinite to break through the dark and narrow womb of the finite.

Professor Elmer V. McCollum, of Johns Hopkins, who has made in the science of nutrition brilliant advances of fundamental nature, once expressed himself to the writer to the effect that he had come to look upon life with singleness of purpose. It is this singleness of purpose that is and will continue to be the unfailing source of his achievements. And it is this singleness of purpose, this whole-hearted devotion to a selfless cause, that is the outstanding characteristic of men of science as well as of men in other human fields of worth-while endeavor, who have left footprints in the sands of time. The great men of science gained their deep insight and far-reaching perspective of the lovely mystery of their calling upon the Gibraltar of character. You have but to delve into the lives of these great personalities to realize the underlying cause of their urge for achievement.

Throughout the ages in every clime, artists and scientists and philosophers have formed a small community isolated from and oft unknown to the great mass of men. They worked on unrecognized and oft under the most trying difficulties. They worked together, as all human beings should, for humanity. While other workers were lost in the maze of competition and bloody jealousy, they understood and practiced democracy and emulation. They maintained themselves by the glow that creative work kindles in the soul, and they kept alive through all the vicissitudes of society the principle of loyalty to the human spirit. In the past they were oft the bright light in the midst of abject darkness; in the present day they are the true aristocrats without whom democracy can not exist. The cultivation of art and science and philosophy and religion in their highest aspects is ever more vitally necessary to the moral condition of the world than material prosperity.

Who shall be called a scientist? Professor Hermann von W. Schulte, dean of the Creighton Medical School, once stated that the highest aim of a medical school should be to turn out young men and young women who would live for the profession and not by the profession. Paraphrasing Professor Schulte's statement of ideals, we may well say that he is a scientist who, possessed of purpose and vision, lives for his work and not by his work. He is a scientist who is saturated with a disinterested love for the universe and whose work is but a revelation of his soul, which exclaims:

I am a part of all that I have met;
Yet all experience is an arch wherethro'
Gleams that untravell'd world whose margin
fades
Forever and forever when I move.
How dull it is to pause, to make an end,
To rust unburnish'd, not to shine in use!
As tho' to breathe were life! Life piled on
life
Were all too little, and of one to me
Little remains, but every hour is saved
From that eternal silence, something more,
A bringer of new things, and vile it were
For some three scores to store and hoard my-
self,
And this great spirit yearning in desire
To follow knowledge, like a sinking star,
Beyond the utmost bound of human thought.

When one trained in science turns his work into drudgery for higher wages he can not achieve science. When he neglects the deeper aims of science and allows the canker of commercialism to bore its devastating way into the finest virtues of his calling, he contents himself with evanescent shadows rather than with permanent realities, with chaff instead of with wheat. He is then no more a scientist than the individual who swats flies is an entomologist; than the helper who washes beakers and test tubes, a chemist; than the man who weeds the garden, a botanist. He who is master of technique only is not a scientist. The maker of rhyming lines with a certain number of feet but without any creative idea or spiritual vision is a versifier and not a poet. The product of his efforts is verse, not poetry. Technique is but a link in the chain, and it can not substitute for essence or make up for vitality. Technique alone is like a ship without a rudder, a lamp without light, a violin without music, a religion without faith. Nor is the man with the "dollar" motive a scientist, "who is sorry that the numerous stars in the midnight sky, which hang in the air for no purpose, do not come to earth for the street lighting and thus help the taxpayers."

It is often said that this is a scientific age, and it is frequently believed that science is concerned not with beauty but with cold facts. This is far from the truth. Facts, even cold facts, can not be discovered without the illumination derived from intellectual beauty and poetic vision. Yet how often do we find the discoveries of science utilized, but the spirit that produces them discarded! When the discoveries of science are used with no sense of the larger service they may render, the shadow alone is taken. The age resulting is an age of science exploited. Whenever such conditions prevail no noble use can be made of the powers placed by science in the hands of man.

Science contemplates nature at work and teaches the dignity of labor. Nature is plebeian. It yields no gains without pains. He who would pluck from her vast treasures must go forth and labor.

Errors like straw upon the surface flow,
He who would search for pearls must
dive below.

Hence the logical existence of the laboratory, the workshop which has succeeded in replacing the old idea of authority with the new idea of first-hand knowledge. There the individual, through self-reliance and self-activity, acquires the fundamental basis of his knowledge by discovering truth for himself. There he learns to substitute facts for appearances and demonstrations for impressions. There he learns from nature, not with the obedience of a slave but with the critical discernment of a judge.

Well may we emphasize the importance of the laboratory by recalling the appeal of Pasteur on learning that work on his own long-looked-for laboratory had ceased:

> If the conquests useful to humanity touch your heart—if you remain confounded between the marvels of electric telegraphy, of anesthesia, of the daguerreotype and many other admirable discoveries—if you are jealous of the share your country may boast in these wonders—then, I implore you, take some interest in those sacred dwellings meaningly described as laboratories. Ask that they may be multiplied and completed. They are the temples of the future, of riches and comfort. There humanity grows greater, better, stronger; there she can learn to read the works of Nature, works of progress and universal harmony, while humanity's own works are too often those of barbarism, of fanaticism, and of destruction.

When we apply the laboratory method, we are struck with the fact that whenever we ask nature a question, we invariably get the same answer, provided we ask the question each time in exactly the same manner. Nature works with regularity, with system. And it is the work of science to discover this regularity by observing phenomena and grouping them according to lines of similarity and of difference. Science classifies knowledge for the purpose of seeking explanations of natural phenomena. And these explanations have been eagerly sought by hundreds of individuals, century after century, oft with no other stimulus than one derived from the feeling and conviction of truth for truth's sake, or with no other motive than the altruistic one of helping forward the march of humanity.

Science impresses the moral lesson that nature works in a spirit of harmony, interdependence, and true democracy. Her results are accomplished with economy, mutual cooperation, and impartiality. Her laws recognize no creed, no race, no tradition, no prejudice. They hold good for the rich and the poor alike. For the individual to be imbued truly with the scientific spirit means, indeed, to breathe the air of undefiled freedom and to saturate his life-blood with an antidote for smallness, narrow-mindedness, and hypocrisy.

Nature idealizes usefulness. Nothing is at rest and nothing stagnates, for nature is dynamic. Every object, animate and inanimate, has its function. Man is not the center of the universe; at best he plays his part. Science impresses him with this fact, humanizes him, and teaches him humility and consideration for fellow-man and fellow-beast. Abraham Coles expresses the same thought in the lines:

> I value science—none can prize it more,
> It gives ten thousand motives to adore,
> Be it religious as it ought to be
> The heart it humbles, and it bows the knee.

Science teaches that "the universe is the manifestation of one grand creative thought, as comprehensive in the diversity of its parts as it is grand in the unity of the whole. These parts have been so wondrously joined and skillfully wrought that each is linked with each, and one with all. In nature's economy nothing is superfluous, and what seems to our feeble vision least important is essential to complete the unity of the plan." In the words of our Longfellow:

> Nothing useless is or low,
> Each thing in its place is best
> And what seems but idle show—
> Strengthens and supports the rest.

As we look into the knowledge so far gathered in relation to natural phenomena, we find that it has become so bulky and complex that it has been necessary to divide it into smaller parcels.

Each such parcel is called a science, and includes more or less a distinct body of knowledge. For the sake of convenience we speak of chemistry, physics, biology, geology, astronomy, although one science at times overlaps the other. In nature there are fine gradations, but rarely abrupt demarcations.

The boundaries between the sciences are arbitrary and tend to disappear as the sciences progress. The principles of one science often find striking and suggestive illustration in the phenomena of another. Thus the most beautiful applications of physics are noted in astronomy, in anatomy and in physiology; the most remarkable uses of chemistry in the field of biology. All sciences gain by mutual support. There are stages in the history of every science when its progress came from applying to its subject-matter wider conceptions of the relations of one branch to another. As a matter of fact, scientific progress consists, for the greater part, in such resorts to a larger synthesis. In the words of James Russell Lowell: "The noblest definition of science is that breadth and impartiality of view which liberates the mind from specialties and enables it to organize whatever we learn, so that it becomes real knowledge, being brought into true and helpful relations with the rest."

The task of discovering particular facts and general laws, of systematizing, classifying, correlating and interpreting has just begun. The astronomer is still engaged in studying the infinitely great. The chemist and the physicist are still investigating the infinitely small—the molecule, the atom, the ion, the electron. The botanist, the zoologist, the physiologist, the bacteriologist are still increasing the rich harvest of interesting phenomena concerning complicated life processes. The psychologist is still delving into the motivity of human action. The embryologist is yet unfolding the first chapters of genesis. The geologist and the paleontologist are still extracting history from the rock of ages. These accumulated treasures, indeed, seem marvelous, and yet, as each year rolls by, we find ourselves, like Balboa, looking down from the mountain top, beholding an infinite and beautiful expanse, yet unfathomed. We feel with Sir Isaac Newton like children gathering shells on the shores of an infinite sea. The vista continues to widen, and new problems, new theories, new viewpoints, loom large before us. To quote Joseph Priestley: "In completing one discovery we never fail to get an imperfect knowledge of others of which we could have no idea before, so that we can not solve one doubt without creating new ones." It seems that

> The unfinished window in Aladdin's tower
> Unfinished must remain.

Shall we therefore give up in despair? By no means. Let us listen to the words of hope uttered by Alfred Tennyson:

> Yet I doubt not thro' the ages one
> Increasing purpose runs,
> And the thoughts of men are widened
> With the process of the suns.
>
> Not in vain the distance beckons,
> Forward, forward let us range,
> Let the great world spin forever down
> The ringing groves of change.

To the investigator in science who chivalrously travels forth to explore the yet untrodden, the work of minute and careful experimentation, close observation and proper deduction seems difficult and at times hopeless. "Oft in the maze, he is hardly able," to use the language of Matthew Arnold, "to see it clearly and to see it whole." But though the roots of science are bitter, its fruit is sweet.

PHYSICAL LAWS AND SOCIAL PHENOMENA

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OF all the phenomena of nature, those presented by the social intercourse of human beings have proved most difficult to cast in the scientific mold. The reasons for this are not far to seek; few phenomena are more complex in their multiplicity of detail, and none are harder to "control" experimentally after the manner of the exact sciences. It was, undoubtedly, just this difficulty of abstracting from the diverse data of society sequences of routine events which could be handled by the scientific method that prevented for so long the growth of a science of society. It was August Comte who first insisted that there really *is* a science of sociology, and, indeed, he considered it the greatest of all sciences, since it includes in its scope all other branches of knowledge. In his discussion of sociology Comte was not content merely to collect and classify observations of social phenomena (in other words, to make a detailed abstract of the available data); he insisted on framing elaborate theories of social phenomena modeled in general after the existing theories in mechanics and physics. This was in line with his positivistic philosophy and led him to carry over into sociology not only the methods but also much of the terminology of the exact sciences. Thus every one is familiar with his social "statics" and social "dynamics," with his social "forces" obeying definite "laws" just as physical forces obey physical laws. More recent writers, particularly Ward, have elaborated these theories, seeking still closer analogy between the social and the physical world. Now I do not question for a moment the great value of using the methods and results of one science in the development of another. Indeed, this is the way all science grows. Nevertheless, in all reasoning by analogy caution is necessary, and it strikes me, as a physicist, that neither the earlier nor the more recent sociologists have been particularly cautious in their use of physical nomenclature. Perhaps some of this has been due to the looseness with which the exact scientists themselves have until very recently treated the terms of their field of work. As an example, I should like to consider the use of the word "force." This originally had a causative significance in physics, but that meaning it has now entirely lost; it now serves merely as a convenient symbol for the mathematical description of the motion and changes in the motion of bodies. This change is in line with the gradually developing conviction that it is no function of science to investigate the "causes" of things, that its purpose is rather to "describe" than to "explain." It therefore seems of doubtful worth to retain the word "force" in social science, for social "forces" do not *cause* social events to happen any more than physical forces *cause* physical events to happen. The use of this word has undoubtedly appeared to give to many elaborate social theories far more validity than they actually possess.

Much the same may be said about the word "law." In carrying over into sociology the physical concept of a "law of nature," it is necessary to understand exactly what is meant by this term. There was a time when such a law was conceived more or less as a command enacted by some divine legislature for all men to obey. Things went as they were observed to do because of the existence of divine law, which kept them from doing anything else. This element of necessity has, however, entirely vanished from the present-day conception. The modern physicist conceives a natural law to be only a shorthand formula of the mind comprehending a brief description (preferably and in the last analysis in mathematical language) of a large group of sense impressions. Physical laws are never forced on man from without; they are the product of man's own reasoning about his experiences in the world. Needless to say, they are in a continual state of change, as man's experiences widen and grow more diverse. It is impossible for a physicist to conceive of laws of society on any other basis. Like the laws of physics, they can be merely generalizations of the mind subsuming sequences of social events. As our knowledge of the ways of society grows, so too these laws will change.

While still observing carefully the precautions emphasized immediately above, I think that there is a fertile field of endeavor open in the application of physical laws to social phenomena. It seems reasonable that among the laws of the physical universe there may be some of sufficient generality to possess significance for the relations of society. In seeking for such it is well to remember that physical laws may be divided into two great classes generally denoted by the terms *macrocosmic* and *microcosmic*. As the words imply, the former have to do with matter on a large scale, in the gross, so to speak, while the latter deal with matter in the little. A few illustrations will serve to make clear the distinction. The Newtonian law of gravitation is a macrocosmic law, for the motions of all gross forms of matter, *i.e.*, matter perceptible directly to the senses, appear to be governed by this law. When we come, however, to the ultimate infinitely small atoms and electrons out of which modern physics supposes matter to be constructed, we find that their motions can no longer be exactly represented by the Newtonian law. New laws, new formulae are needed to describe the latter, and these are termed *microcosmic* laws: they deal with phenomena on a very small scale. Furthermore, the law of the conservation of energy, which teaches that the total amount of energy in the universe is constant and that all we can do is to transform it from one form into another, is a macrocosmic law, while the law or laws governing the interchange of energy among atoms and molecules are microcosmic laws. In other words, we conceive the atom as the microcosm, so to speak, and the gross material as the macrocosm.

Now under which of these two classes will the laws of social relations fall? Is it not clear that while the individual person is the social microcosm, the social group is the macrocosm? When we look, therefore, for physical laws which are of immediate application to social phenomena, we are inevitably led to the macrocosmic variety.

It is not my purpose here to enter on any thoroughgoing investigation of all the analogies existing between the physical and social macrocosms. But I have been led recently to consider one general physical law which seems to be of great significance in sociological theory, and a discussion of this may well serve as an illustration of the kind of field of endeavor opened up by the above considerations. I shall begin with a description of the physical meaning of the principle I have in mind, using first a very humble example.

Every one must have observed that when a bicycle or automobile tire is pumped up rather quickly it soon becomes hot, and the hotter it becomes the harder it is to pump. At first thought there seems nothing more remarkable about this than the fact that part of the work spent in the pumping reappears in the form of heat, which is unable to escape from the compressed air fast enough for the latter to remain at its previous temperature. But if we inspect this phenomenon more closely we find matter of greater significance. It will be recalled that when a gas is heated it expands, as witness the hot-air house-heating system. We must therefore conclude that the hot air in the tire also tends to expand against the force that is compressing it. To use a more personal mode of expression, we may say that the air *resists* the compression and alters its condition in order to nullify as far as possible the action brought to bear on it; it thereby acts to retard the compressing process and to make it harder to perform.

This simple phenomenon is an example of a very profound law of nature well known to students of physics and chemistry. In technical language it is called the principle of *mobile equilibrium;* for our purposes it might be more appropriately named the principle of inertia, since it expresses so clearly the inertia or reluctance to undergo change which characterizes every body in the physical universe. In order to state the principle in general fashion, I must first make plain what is meant by a physical *body* or *system* of bodies and the *state* of such a system. By the former term physicists denote merely an aggregation of physical particles in gaseous, liquid or solid form, while the state of a system is simply its physical condition at any instant of time, and this is conceived to be determined by a number of factors. Thus we speak of the *pressure, volume* and *temperature* as the factors which fix the state of a gas, since when these are given we know or can determine mathematically all that is necessary to know or indeed all that *can* be known about the gas in so far as it is an object of our sense impressions. So also the *electromotive force, current, resistance, inductance* and *capacity* are the factors which determine the state of an electric circuit, as, for example, a radio circuit.

Now any physical system is said to be in a state of equilibrium when the various factors fixing its state do not of themselves tend to change. What the principle of inertia says is this: if any one of the factors determining the state of a system in equilibrium is altered in any way, the other factors will themselves so change as to *oppose* the change in the first and partially annul it. A system in equilibrium thus betrays a latent but powerful conservatism. It prefers, so to speak, to remain as it is. It detests alteration. We hardly need add that this principle is of the widest generality in nature. Indeed one can hardly mention a single law governing physical or chemical change which does not somehow involve the principle of inertia.

Does it not seem plausible that we have here a law manifestly macrocosmic in character, the application of which extends far beyond the bounds of the natural sciences? As the sociological analogue of a physical system let us conceive of a social system comprising a number of human individuals grouped in a definite way and for a more or less definite purpose. Like the physical system this social system will have its condition defined by certain factors which we may call social factors. Thus the family, the kinship group, the state, are illustrations of what I mean by a social system. Likewise the church and the school. Among the prominent social factors we may include the physical environment, the mental and moral equipment of the individuals making up the system (*i.e.*, their reason, passions, hopes, fears, etc.), and the traditions which the group has accumulated during its existence. These factors are closely related to the social "forces" of the sociologists, but for the reasons amply set forth above, I prefer not to use this name. I can not look upon them as having causative significance, they are but symbols with which to describe the phenomena displayed by social institutions. They differ from the factors defining a physical system in one important particular, *viz.*, in the majority of cases they are much more numerous and in consequence less sharply defined and less susceptible of precise measurement. To illustrate: we can measure with extreme accuracy the pressure of a gas at any instant, but it is a far more complicated matter to estimate the traditions of a race and their influence on its present state. Nevertheless, the extent of our knowledge of any social system is directly proportional to the exactness with which we are able to estimate the factors determining its condition at any time. In this sense the analogy between physical and social systems is quite complete. But have they no other aspects in common? They have; and it is here that the principle of inertia plays its rôle. A social system, like its physical analogue, is capable of existing in a state of equilibrium, which is, moreover, susceptible to change from without. To be sure, the changes in social institutions would seem to indicate that social equilibrium is of a rather unstable kind. Yet if we study any particular social institution, as, for example, the family, we find great periods during which change, though present, is very gradual and in which, therefore, a kind of equilibrium may be said to be established. These facts are well known, but the really important point which I have never seen emphasized is that while social systems *do* change in time they also resist change. Like physical systems they tend to oppose any alteration imposed from without. When an external influence is brought to bear on one of the factors defining the condition of a social system, the other factors alter to nullify the change as far as possible. Every social system is essentially conservative.

Has it not often seemed strange that all the movements toward social reform which most persons are now inclined to recognize as having benefited the human race, were bitterly opposed, nay, often fought with tooth and nail? And does it not appear equally curious that the great political and ecclesiastical changes which have taken place in recorded history have in almost every case been at the expense of continual wars and untold bloodshed? Yet these are but illustrations of the generalized principle of inertia. No social institution in temporary equilibrium consents to change without resistance, without a struggle. Of the many examples which history affords two will suffice for our purpose here. Let us recall the great efforts of men with broadened minds and liberal ideas to reform the decayed and almost outworn social structure of the French nation prior to 1789. Let us also remember that these attempts led to such vehement opposition to change within that structure that revolution and temporary chaos followed. As another illustration may be cited the attempt to alter the prevailing manufacturing methods in England in the early part of the nineteenth century. The resistance this aroused, the riots and other disturbances which played so large a part in the industrial revolution form an important section in English social history. In each of these cases we see a social system in transient equilibrium opposing change in the factors which defined it.

It is important to note, however, that the inertia manifested by a social system does not enable it wholly to avoid change. Indeed, it is a cardinal feature of our principle that the system in the very act of resisting change *alters* the factors that determine its state. By this very alteration the system takes on a new guise different from the old; it has actually evolved. Thus we may look upon the essential conservatism of social systems as containing in itself the germ of change, of evolution. In any instance the alteration brought about may be expected to be a compromise between what the external influence would effect if unresisted and the original state of the system. Such compromises are characteristic of every phase of society. At this moment a particularly interesting illustration is afforded by the modern problem of the family.

That the family considered as a social system is to-day in a state of great instability, no one can doubt. Many are the external influences which are affecting it, among these being the freer status of women, the modern feministic movement and the rapid increase of industrialism. These conditions have been working slowly for some time, and for this reason the inertial resistance to them is not so evident. A more radical blow at the family is the quite definite movement on the part of the communistic theorists to abolish marriage altogether, substituting for it free love or what amounts to promiscuity in sexual relations. Experimentation in this direction is already taking place in Russia. If we may accept as reasonably correct the accounts reaching us from that country, the resistance which this movement is arousing, particularly among the peasantry, bears witness to the innate conservatism of this institution. The family is not yet dead nor will it wholly die. At the same time the resistance to change is causing a modification in this institution which will mean a genuine evolution in its character. The social evils already attending this attempt to subvert the older marriage relation, the most serious of which is doubtless the utter degradation and ruin of childhood, will act to bring about a different attitude toward the family—whether more wholesome than the old is for philosophers to discuss. What we may be sure of is that there will be definite change succeeding the present chaos.

By this last illustration we are brought to another important aspect of the principle of inertia. In physical changes the more rapidly the external influence attempts to work, the greater is the resultant resistance and the greater is the amount of work which must be expended to overcome it. To revert to our original simple illustration, the *faster* we try to pump up the bicycle tire, the hotter it gets and the more difficult we find the task. In the same way every one must have noticed that it is harder to open a heavy revolving door *rapidly* than it is if one is content to do it slowly. Likewise in social phenomena, the more radical and impetuous the reform sought in a social system the greater is the opposition aroused and the more difficult it is to overcome this opposition. Conversely, a more deliberate change is not so hampered. In our comments on the present state of the family we saw that the influences operating most largely (at least in our own country) to bring about change in this institution are proceeding so gradually that the resistance to their action attracts less attention and indeed needs careful analysis to detect it, while the more radical Russian movement is arousing correspondingly radical opposition, with the consequent chaotic results so evident to observers in that country.

The principle of inertia thus leads us here to glimpse an extremely significant generalization regarding all changes in social systems. This affirms that development in society, like development throughout all the natural universe, in so far as we are able to observe it and its effects, proceeds with extreme slowness, that there is no more real basis for a cataclysmic theory of society than there is for a cataclysmic theory of natural phenomena as a whole. Even the occurrence of revolutions and other upheavals, which may seem at first thought to give the lie to this thesis, really do not contradict it; such events are but the inevitable turbulences in the flow of social phenomena. No one will deny their contribution to the development of society, but the important point is this: the changes which they seek to bring about all at once actually prove to require years for their maturity. All this is bound up in that very resistance to alteration, that innate inertia which is a fundamental characteristic of all social systems.

Many of us are apt at times to grow pessimistic over the wave of radical reform propaganda which threatens to engulf our already much buffeted institutions. May we not extract a grain of comfort by meditating on the principle of inertia? No social system has ever been completely overturned all at once and the probability is relatively enormous that no social system ever will suffer this calamity. Changes there will be and great ones, but they will come slowly; all efforts to accelerate matters will meet the same fate as in the past—stubborn resistance and decelerating opposition. If the doubter asks why this should be so, I can say only that it is not within the province of science to answer this question. The "why" belongs to metaphysics; science is content with the "how." But the practically minded doubter may yet counter with the accusation that our contemplation of the principle of inertia is unethical, since it may cause people to shirk their social responsibilities under its comforting shelter. This again is a matter for the philosopher to settle. I can state only that our principle has no power to "cause" anything in the metaphysical sense. It is a generalization of experience and describes briefly how things appear to go. I must confess my feeling that in it we catch a glimpse of a law of nature transcendent in significance. I believe no science of society can afford to neglect it.

CREDULITY VERSUS SCIENTIFIC DEMONSTRATION

By T. SWANN HARDING

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In the early seventeenth century Nicholas Culpepper, "Gent, Student in Physik and Astrology," published "An Astrologo-Physical Discourse on the Vulgar Herbs of this Nation; Containing a Compleat Method of Physick, Whereby a Man May Preserve his Body in Health or Cure Himself Being Sick, for Three Pence Charge, With Such Things Only as Grow in England, They Being most fit for English Bodies." It is superfluous to add that long titles were not unfashionable in those days.

In this really remarkable work Culpepper recommended arch-angel (not Gabriel, but the weed sometimes called dread-nettle) to make the heart merry and to drive away melancholy. He extended a balm to cause the mind and heart to become blythe and prescribed motherwort to drive melancholy "vapours" from the heart. He sapiently remarked, "the chief use of them is for women, it being an Herb of Venus and may be found in the guide for women. Balm is a herb of Jupiter. Mother wort is owned by Venus."

All this was offered for three pence. But we advanced humans of to-day are quite incredulous. We may pile up a hundred thousand dollars annual profit for a fakir who dispenses snake oil for rheumatism or for deafness. The substance may consist of the oils of wintergreen, eucalyptus and neatsfoot combined with camphor, mustard and benzol. The snake may be altogether absent and the oil demonstrably impotent against whatever is meant by rheumatism or in helping deafness. But we enrich the manufacturers.

Or we may believe in Arthur Crane, "The Great Exorcist," who, prior to 1920, became wealthy by bidding his clients to direct their minds toward him at specified times when he consented (for value received) to be receptive, and to say, "I am unloading all my cares upon Arthur Crane." Thousands prayed, and paid, and were cured and, until an inhuman postoffice department interfered, Arthur prospered. Nevertheless, we have advanced. Certainly we are very incredulous regarding such phantasies as that of Culpepper, Gent.

But legitimate scientific research of undoubted authenticity tends constantly to strain our credulity. There is a form of ice which can only exist at a temperature of 175° F. and under a pressure of a hundred tons to the square inch. What can we do about that demonstrable fact except believe and let credulity go hang?

Nothing seems more prosaic than the segment of science which concerns itself with the nutrition of cows and goats. The cow is, to be sure, a placid and virtuous animal but is certainly not one to get excited over; and, whatever may be said for the goat, it does not readily lend itself to lurid and fantastic speculations. Yet right here there is the positive thrill of the almost incredible, which is none the less the experimentally demonstrable. Moreover, since all such investigation upon lower animals has its ultimate application to the biped permitted by an indulgent fate to abuse a very attractive planet, these findings have human importance as well as human interest.

Although our subject is not these too volubly discussed entities called vitamins, we shall have to mention them in passing to lead up to our subject. The vitamins are, just now and before they have a chance to be renamed, fat soluble A, promoting growth and essential to the young, water soluble B, the antineuritic and growth-promoting, C, the antiscorbutic, fat soluble D, the antirachitic and again essential to the young, and E, the reproductive vitamin Evans discovered. Though discussion has raged and claims have been made in unprofessional profusion, Funk's statement on "Who discovered Vitamins" in *Science* for April 20, 1926, probably apportions the credit as equitably as it can be apportioned.

Many investigators, for instance, Drummond, Channon and Coward (*Biochemical Journal,* Vol. 19, p. 1047, 1925) accredit the discovery of vitamins to Sir F. Gowland Hopkins, of Cambridge University. In 1906 Hopkins noticed that experimental animals died on a diet which was chemically adequate. He then said, "But further, no animal can live upon a mixture of pure protein, fat and carbohydrate, and even when the necessary inorganic material is carefully supplied the animal still can not flourish." He suggested that accessory food factors, then unknown, are necessary to maintenance and growth.

Hopkins's statement does indicate unusual perspicacity, but it is speculative rather than directly evidential. As a speculation it was not an early one. As Van Leersum notes in *Science* for October 8, 1926, Pekelharing, professor of physiological chemistry and histology in the University of Utrecht, made a similar observation in an address to The Netherlands Medical Association in 1905. And Bunge had the idea as early as 1891.

Said Pekelharing: "There is a still unknown substance in milk which, even in very small quantities, is of paramount importance to nourishment." Said Bunge, doubtless with reference to Lunin's work in his laboratory in 1888, mice "are unable to live on proteins, fats, carbohydrates, salts and water," for "other substances indispensable for nutrition must be present."

Casimir Funk himself recognized the existence of vitamins, comprehended their real importance in nutrition, made the first chemical study of B and acted as a catalyst to further investigation. Credit must really be divided among many workers—Bunge, Stepp, Röhmann, Eijkmann, Schaumann, Suzuki, Pekelharing, Hopkins, Evans, McCollum—to name a few.

But enough of history, though it is interesting to get it properly straightened out. What are these vitamins? As reference to any recent work on nutrition will show their discovery completely demolished much earlier work on animal feeding which had been assumed correct for all time. What motivates these vitamins? How do they work? Are they obscure catalysts like enzymes?

Enzymes have long been obscure organic bodies capable of enormous amounts of work. Thus invertase can split fabulous quantities of cane sugar into its two constituent sugars, glucose and fructose, and it never tires. Once successfully extracted from the solution of the simpler sugars which gradually impede its progress, the invertase, however elusive, is ready to do just as much work over again as often as you like. Its capacity is infinite. Zymase, rennin, pepsin, thrombin and other enzymes are similar mysterious prestidigitators—long perplexing science.

But at last *Science* for November 12, 1926, reported the actual crystallization of an enzyme by Dr. James B. Sumner. It is urease, which converts urea into ammonium carbonate, to the great advantage of vegetation. It proved to consist of octohedral crystals slightly larger than blood corpuscles. It is a protein. Yet vitamins yielded to crystallization even earlier than enzymes.

At least *Science,* in the issue for November 14, 1924, carried Atherton Seidell's account of his crystallization of a vitamin. He gave a history of previous work and then described the isolation of a solid crystalline material of definite melting point which had the properties ascribed to vitamins A, B and D. He stated that vitamins are not enzymes. The isolation of a crystalline substance uniformly marks a great advance from the standpoint of chemical research. Yet there remain mysteries that even vitamins do not seem adequately to explain. Indeed, these new scientific strains on our credulity seem more likely to explain the vitamin mechanism than the other way around.

During recent years the science of nutrition has tended to curious quirks which would have horrified orthodox scientific investigators only a few years ago. So strange are the implications of these new discoveries in nutrition that they sound like heroic journalism rather than sober articles in the *Journal of Biological Chemistry,* which Haldane rightly says "one reads at one's leisure."

It has long been known that if a cow, for instance, be fed a ration deficient in the classic elements of nutrition—protein, carbohydrate and fat—this ration is injurious. But more recently a number of research investigators have shown that mineral elements, like calcium and phosphorus, which occur in the ration in very small quantities, play a rôle of unexpected importance. It has been fairly well established that cows fed upon a ration deficient in calcium abort readily, give a decreased milk yield and become predisposed to pathological conditions of obscure etiology.

Thus timothy hay, which is deficient in calcium, will, if used exclusively for the animal's roughage along with a grain ration ample in all other constituents including phosphorus, not only cause faulty assimilation of calcium but of the phosphorus as well. It thus acts injuriously. It is obvious, then, from the standpoint of the older chemistry, that all one needs to do to make timothy hay a satisfactory food is to add an appropriate amount of some soluble calcium salt. This is precisely not the case, though.

Timothy hay with an artificially added mineral supplement to atone for its calcium deficiency remains an unsatisfactory feed. Alfalfa hay, containing about one and one half per cent. calcium (in lieu about .3 per cent. for timothy) is satisfactory, if properly cured, but if improperly cured, alfalfa is also unsatisfactory, regardless of its calcium content. In the light of the older chemistry such a phenomenon is mysterious, unless we call to our aid a catalyst—a substance which will by its mere presence cause chemical action in two other substances without itself entering chemically into the reaction at all.

For years catalysts were great mysteries. To-day they are being very gradually explained. The timothy-alfalfa problem has, however, not yet been solved. But the term vitamin may be used to designate the activating agency which rendered properly cured alfalfa so nutritive. Of course the calcium in the poorly cured alfalfa may occur differently combined chemically from that in well-cured alfalfa. Or it may differ in its physical state. But more likely the presence or absence of a vitamin causes the result that we observe. Yet another more extraordinary explanation suggests itself and there is ample experimental evidence to give it considerable foundation.

Rats and human beings are subject to a disease associated with vitamin and calcium deficiency called rickets. Faulty calcium and phosphorus metabolism cause this disease. Cod liver oil is antirachitic in that, by its vitamin content, it so regulates utilization of calcium and phosphorus by the body that normal health and growth may be maintained on a diet actually deficient analytically in these two elements! As the *Journal* of the American Medical Association said editorially, it is most extraordinary that a substance containing neither calcium nor phosphorus will enable the body so efficiently to utilize grossly deficient amounts of these two elements that the individual retains normal health. But this is a demonstrated fact.[1] The anti-rachitic and growth-producing properties of cod-liver oil have therefore been presumed to be due to a vitamin.

Then Steenbock, of Wisconsin, began to feed certain rats cod-liver oil in order to improve an otherwise deficient diet. These rats were kept in a cage together with others which did not have the necessary cod-liver oil supplement. To his amazement the rats which were not fed the oil retained their health and grew normally, quite like the others. Finally he remembered that all the rats were exposed each day to the light of a mercury vapor lamp and also that Huldschinsky had, some years before, demonstrated that rickets could be cured by exposure to the ultra-violet rays from such a lamp. This was significant.

When the rats were separated and none of them exposed to the lamp or to sunlight, those not fed the oil became rachitic. If, however, the poorly fed rats were exposed for a few hours daily to sunlight or to the mercury vapor lamp, thus irradiated, they remained in normal health. More curiously still, if the rats which were irradiated were then permitted to associate with unirradiated rats on a deficient diet, the latter also remained perfectly normal. Finally, it was found that if an oil, like linseed oil, which is not normally anti-rachitic, was irradiated with sunlight or light from the mercury vapor lamp, it acquired anti-rachitic properties.

This indicated that vitamin properties, or vitamins, were sometimes generated photo-synthetically—by light—just as sugar is manufactured in plants. Steenbock sent an early, preliminary report of his work to *Science*, where it appeared September 5, 1924. Immediately Hess, of New York, wrote to *Science* (September 19, 1924) confirming Steenbock's work, but claiming priority on his part. He too had irradiated various oils and had found them anti-rachitic when fed.

Hence vitamin D effects are present in hitherto inert oils after they have been exposed to ultra-violet rays. Hess also found that he could easily activate the important human fat cholesterol and impart anti-rachitic properties to it. This is significant because cholesterol occurs prominently near the surface in the animal organism and its analogue, phytosterol, is similarly prominent in the vegetable world and can likewise be activated by light. Neither fat is normally anti-rachitic. Later still the anti-rachitic part of an oil or fat could, after its irradiation, be separated from the rest of it and shown to be a chemical entity.

Further investigations on the irradiation of cholesterol led to the separation of the irradiated substance, by fractional precipitation, into an anti-rachitically active oil and an inactive portion, presumably unchanged cholesterol. This was done both by Koch and coworkers, in Chicago, and by Hess and coworkers, in New York. About 5 per cent. of the anti-rachitically active oil was gotten. It differed chemically and physically from cholesterol. Still more recently, 1927, Hess has questioned whether pure "cholesterol itself developed anti-rachitic properties through ultra-violet light irradiation, or whether it is not rather some contaminating substance intimately associated with it which acquires this specific property."[2] Here the matter rests at this writing—early March, 1927.

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[1] This is from the *Journal* of the American Medical Association, Vol. 83, page 1169. To be strictly exact it must be added that in 1925 apparently reliable work by H. C. Sherman (*J. Biol. Chem.*, LXIX, pp. 429–461) showed that cod liver oil alone would not render the body calcium of rats normal on a low calcium ration; to effect this calcium lactate must be fed in addition to the cod liver oil. The incident will illustrate the dangers of attempting to abstract science progress popularly in definite terms. This work of Sherman's also leads to the reflection that while vitamin D and ultra-violet light may be very essential factors in healing rickets and do very materially affect the calcium and phosphorus content of the blood in that disease, other factors may act also to control calcium metabolism in a normal animal with a normal blood calcium and phosphorus, *e.g.*, a lactating cow. This view is sustained by the fact that cod liver oil added to the ration has not, on certain occasions, put a lactating cow in positive calcium balance, (Meigs, Turner, Harding, Hartman and Grant, *J. Agr. Research*, XXXII, pp. 855 and 859).

About this time Kugelmass and McQuarrie, of Yale, published also in *Science* a note saying that rays emitted by cod-liver oil would fog a photographic plate with a quartz, but not a glass, plate between. Ultra-violet rays can penetrate a quartz but not a glass plate. The indication was that cod-liver oil emitted such rays and that perhaps their liberation in the body when cod-liver oil was taken accelerated or activated calcium and phosphorus metabolism.

Unfortunately, however, it is necessary in the interests of strict veracity to add a damning fact of the type usually omitted in records of scientific progress as prepared for non-scientists. Schlutz and Morse in 1925 (Proc. Soc. Exp. Biol. Med. 22, 555) could not confirm the findings of Kugelmass and McQuarrie. They passed a slow stream of oxygen over the surface of some cod-liver oil in darkness and left the photographic plates exposed to it for sixty-six hours. In spite of the fact that the cod-liver oil was high in vitamin activity, the plates were not fogged. Here this matter rests just now.

In 1926 Weston A. Price reported at the spring meeting of the National Academy of Science in Washington that he found calcium deficiencies improved by rubbing cod-liver oil on inflamed joints. This would indicate absorption of a therapeutic agent through the pores, a thing long contested in medical journals, which have but recently published other evidence that such absorption does sometimes take place. Price found that the calcium content of the blood stream was increased by such application of an oil containing no calcium whatever. Chickens on a deficient ration could be kept in perfect condition by rubbing them with cod-liver oil. While this work remains so far unconfirmed it is extremely interesting and suggestive.

In the December, 1925, *Journal of Biological Chemistry* appeared another notable contribution to the subject from Hart and Steenbock. They demonstrated that exposure to ultra-violet light influences calcium and phosphorus storage in lactating goats. Exposure of the goat to a mercury vapor lamp for twenty minutes a day changed a negative to a positive calcium balance; *i.e.*, the animal stored rather than lost calcium. This was done on a ration manifestly deficient in the anti-rachitic factor. They concluded that sunlight is probably more important to calcium and phosphorus assimilation than is green plant tissue. In 1927 they found, however, that a cow did not react similarly to irradiation by ultra-violet light; its calcium and phosphorus metabolism and its milk yield remain unaltered (*J. Biol. Chem.*, May, 1927, p. 59).

These workers at the same time showed that milk can be rendered anti-rachitic by ultra-violet irradiation, another case of synthesizing a vitamin. Luce (*Biochem. J.*, 18, 716 and 1229, 1924) also showed that the milk of pasture-fed cows had a definitely higher anti-rachitic value than milk of the same animals stall-fed on a winter ration of roots and cereals. In testing such milk on rats it had to be remembered that a lack of Vitamin D inhibits growth as well as causing rickets. In later experiments D was supplied to the rats by feeding irradiated vegetable oils, but no A was supplied. Chick and Roscoe (*Biochem. J.*, 20, 632, 1926) then found that the Vitamin A content of milk does depend on the ration and the Vitamin D content on the exposure to sunlight. A cow fed fresh grass in a dark stall gave milk low in D; she therefore manufactures D photosynthetically but does not manufacture A, which she merely passes on from the food intake. These findings had wide significance from the standpoint of milk production and the care of lactating animals. But what about human beings?

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[2] Proc. Soc. Exp. Biol. Med., January, 1927, XXIV, 369. It was hinted in the same publication (XXIV, 461) that since irradiated ergosterol brought about healing of rachitic bones when but .003 mg of it per capita was fed daily to rats, it might possibly be associated with cholesterol in the body and cause the effects hitherto attributed to irradiated cholesterol. This work is by Hess and Windaus. Rosenheim and Webster, in Great Britain, also activated cholesterol with ultra-violet light and separated the active fraction (*Biochem. J.*, 20, 537, 1926).

This question was answered by Dr. Alfred F. Hess in the January 1, 1927, issue of the *Journal* of the American Medical Association. The milk of a nursing mother was found to be incapable of curing rickets in rats. But after the woman had been irradiated with the ultra-violet mercury vapor lamp, her milk did very certainly cure rickets in rats. What was more interesting the pooled blood of these animals fed human milk after the irradiation showed more calcium than the pooled blood of the rachitic rats.

Dr. Hess placed the lamp at a distance of from thirty to sixty inches from the mother. She was irradiated every other day for a period of one month. The irradiations were at first carried on for but a few minutes; in the end they lasted nearly an hour daily. The conclusion of this work stated, among other things: "It is suggested that such irradiation be employed in order to protect infants from rickets and nursing women from excessive drain of calcium and phosphorus."

It is to be remembered that dried milk may also be endowed with high antirachitic and calcifying properties by ultra-violet irradiation, and that winter and summer dried milk, while differing naturally, have the same potential capacity for such endowment. (Supplee and Dow, *J. Biol. Chem.*, June, 1927, p. 617.)

These developments are really surprising when viewed coldly. They concern matters which would have been dismissed as half-mystic nonsense by the practical investigator just a few years ago. In fact, when these revelations were first made very many good research workers laughed at the ridiculous idea. While science must be on guard against ignorant credulity, it should not dismiss as obviously false or absurd statements which may, at first hearing, seem too highly speculative to merit serious consideration. Much that seems superficially contrary to reason is, in the last analysis, most reasonable of all.

It is easy to imagine the merry ridicule one would have met a few years ago by suggesting to some practical husbandryman that holding a lamp over a goat a few minutes every day would make it a very much better goat or to the practical physician that certain lamplight might act therapeutically on nursing women. Yet these are to-day known facts.

Faith is precisely the same quality in science as in mysticism or in pure speculation. But in the former case it is used efficiently and with discretion; in the latter two it is used profligately and without discretion. Even magic only errs by assuming implicitly what science seeks to demonstrate explicitly—that phenomena do follow laws which may usefully be correlated and heeded, but such an error is utterly devastating to scientific method. It is the highest art of the best investigators to preserve imagination and healthful credulity; while at the same time refusing to permit facile generalizations to leap madly ahead of established experimental data to questionable or totally false conclusions.

SOME STATISTICAL ASPECTS OF LIVINGNESS

By Professor D. FRASER-HARRIS

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It was well said by Lord Kelvin that a subject does not really become a science until you have applied the method of measurement to it. Thus as regards electricity, so long as electricity consisted of rubbing a piece of amber and making it attract some bits of paper or of stroking a cat's fur "the wrong way" and getting sparks out of it, it was not a science.

But so soon as men were able to measure the intensity of a current and the quantity and "potential" of a charge, then the science of electricity had been born.

Now the science of biology, although it has made immense advances towards accuracy and definiteness in the last thirty years, suffers from this very drawback that as yet it has not been able to express its chief concern—life—in terms that are quantitative. You are alive; but how much alive are you? Is your heart more or less alive than a year ago? These are not foolish questions, although at present they may be unanswerable.

Clearly, a person about to die of a wasting illness is less alive than a healthy athlete just awakened from sleep. A person suffering from melancholia is certainly less alive than a prize-fighter about to enter the ring; but by *how much* less is, at the present moment, an extremely difficult thing to say. To measure the degree or intensity of livingness we must first agree upon standards or criteria. An example of how the problem has been solved in the case of vegetable organisms may help to make things clearer.

The dried seeds of a plant are presumably not dead, else when sown in the ground they would not grow up into plants as every one knows they do. But by merely looking at seeds, no one could tell whether they were alive or dead. A seed, having germinated, proves it *was* alive, but you have lost your seed though you have gained a plant.

In any packet of seeds by no means all are alive; but at the present time we have no simple method of pronouncing on their livingness, and certainly no simple method of telling how much any one seed is more alive than another.

The physiologist, the late Professor Waller, F.R.S., devised a method depending on the use of the galvanometer—an instrument in which the oscillations of mercury produced by the passage of electric currents can be photographed on a moving, sensitive surface.

It makes no difference whether these currents are produced by non-living, by vegetable or by animal matter.

Dr. Waller placed a seed of the scarlet runner (Phaseolus) in connection with a sensitive galvanometer, and stimulated the seed by passing through it the discharge from a Leyden jar. As a result of this, the seed made a "response" whose electrical counterpart was seen and measured in the galvanometer. The electromotive force of these momentary currents can be measured in fractions of a volt.

The following table gives the results at a glance, when seeds ranging from one to five years old were stimulated:

Years Old	Volts
1	0.0170
2	0.0050
3	0.0043
4	0.0036
5	0.0014

These investigations are particularly interesting both on account of their novelty and their exactitude. We can say, for instance, that the four-year-old seed was 4.72 times less alive than the seed one year old. Or we can state that the one-year-old seed was twelve times more living than the five-year-old. The great accuracy of this method is due to the fact that the measurement of the electromotive force of currents in the galvanometer is so precise.

When we come to animal organisms we have a problem which in the nature of things is much more complicated.

For, first of all, shall we try to measure the degree of livingness of the body as a whole or only of some organ or tissue within it?

Either method is theoretically possible.

There should be methods of determining the vitality of the entire animal; there must be more vitality in a healthy schoolboy than in an octogenarian—but *how much* more? The heat produced and lost by the body should be a useful criterion; and there is a method of estimating the heat-loss and expressing it in calories per unit of skin-surface per hour.

By this method it has been ascertained that the heat lost per square meter per hour by the adult male at rest and at a time about twelve hours from the last meal is forty calories, that by the female thirty-seven.

Physiologists have for long had reason to believe that the intensity of metabolism (that is, the totality of the chemical activities of living tissues) is rather more intense in the male than in the female; and now we have statistical evidence of this.

The case of the focussing power of the eye may suffice as an example of a statistical method applied to a single organ. We see a near object distinctly when its image is sharply focussed on the sensitive retina at the back of the eye; this image-formation is accomplished by the elastic crystalline lens becoming thicker at its center, a movement effected by the activity of a special circular muscle.

The older a person grows, the less elastic does the lens become and the feebler is this muscle of focussing. If then we make an estimate of the power of the lens and the muscle at any age, we can compare this with their powers at an earlier and at a later date. The refractive power of a lens may be stated in "diopters," one "diopter" being the power of a lens of one meter focal distance. By using this conventional standard, it has been ascertained that if we call the power of the lens at sixty years of age unity, then at ten years of age it is 14; at fifteen, 12; at twenty, 10; at thirty, 17; at forty, 4½, and at fifty, 2½. At seventy years of age the lens is only one quarter as powerful as it was at sixty.

In this way we have the statistical aspect of the decreasing vitality of the human crystalline lens.

Let us now turn to another tissue, the nerve, and view the statistical aspect of its activity. We shall employ as a criterion the speed of the propagation of the nerve-impulse in the nerves of different animals arranged in an ascending zoological series.

The notion underlying this is that the intensity of nervous vitality is less in a lowly than in a higher animal.

We do not for a moment mean to imply that because we call an animal "lowly" it is not as perfect as some other animal we call "higher." Each animal is perfectly adapted to its own surroundings, and each type performs perfectly its own particular functions. A snail is perfectly adapted to eat our young cabbages in a midsummer night, a frog is perfectly adapted to leap about the marshes and catch flies; but no one would maintain that the nervous system of a snail or a frog was to be considered on the same functional plane as that of a human being.

Accordingly, we find the most striking quantitative differences between the various rates of propagation of nerve-impulses in animals arranged in an ascending scale. The rate is stated in meters per second:

Animal	Rate of Nerve Impulse, Meters per Second
Limulus, a crab (nerves of heart)	0.40
Limax, a slug	1.25
Cuttlefish	2.00
Limulus (nerves of body)	3.25
Hagfish	4.50
Lobster	12.00
Snake	14.00
Frog	28.00
Man	120.00

From these results we are permitted to say that the intensity of livingness in a human nerve is ten times that of the nerve of a lobster, thirty times that of a hagfish and sixty times that of a cuttlefish.

There is yet another line of quantitative investigation which can be followed out, namely, to estimate the amount of oxygen which a unit weight of a certain tissue absorbs or uses up in a known time. Evidently this is a very reliable measure of livingness, because, as is well known, the more active or alive a tissue is, the greater is the amount of oxygen which it utilizes. When it is dead it utilizes none.

The physiologists can estimate the amount of oxygen in the blood going to a muscle and also the oxygen in the blood coming from the muscle, the difference between these being the quantity of this gas retained by the muscle selected.

We state the results in cubic centimeters of oxygen per gram of the muscle per minute.

In the following table, a muscle in four different physiological conditions was investigated—fully active, gently active, in true physiological repose (that is, not contracting at all), and finally, after its nerves had been severed.

State of Muscle (cat)	Cc of Oxygen absorbed per Gram of Muscle per Minute
Fully active	0.08
Gently active	0.02
In true physiological rest	0.006
After nerves were cut	0.003

Here we have a quantitative chemical method which enables us to say that a muscle in full contraction is thirteen times as active as it is when at rest.

And further, we see that after a muscle has its nerve supply done away with, the vitality falls by one half of its resting value. By this chemical method it can be stated that a healthy, fully contracted muscle has twenty-six times the vitality of the same muscle after all its nerve influences have been abolished.

This same chemical method has been successfully applied to the study of the livingness of the heart of the cat. It was found that when that organ was beating normally, it utilized 0.014 cc of oxygen per gram per minute. When it was artificially stimulated to extreme activity, the figure rose to 0.08; but when, on the other hand, it had become slow and feeble, the figure sank to 0.007. It would therefore appear that the livingness of the heart beating normally is twice what it is when the heart is beating only slowly and feebly.

The living glands have been investigated in exactly the same way, as the following table shows:

Type of Gland	Cc of Oxygen utilized per Gram per minute
Pancreas (acting normally)	0.03
" (stimulated artificially)	0.10
Kidney (acting normally)	0.03
" (stimulated)	0.07
Liver (in inanition)	0.005
" (well nourished)	0.05

Thus it would seem possible that the pancreas (sweetbread) can be made to live three times as intensely as it normally does. The liver in a starving condition is ten times less alive than when thoroughly nourished. We have known for a long time that all depressing conditions, of which starvation is one, tend to diminish vitality, but it is only quite recently that we have obtained a statistical expression for that diminution.

A rather different line of research may be pursued.

The more sluggish a muscle or other organ is, the longer it can survive after the death of the animal of which it was a part. For it must be remembered that an animal can die as a whole (somatic death) and yet its various tissues, for instance, its muscles, can live for longer or shorter periods.

Thus, whereas the muscle of the human heart is alive two hours after bodily death, the body-muscles are alive five to six hours thereafter. And whereas the muscles of a rabbit will live for eight and a half hours after the death of the animal, those of a sheep will survive for ten and a half, those of a dog for eleven and three quarters, those of the cat twelve and a half and those of the frog for from twenty-four to forty hours.

This is an interesting statistical aspect of vitality.

There is still another method open to us, at least as regards a muscle, namely, to calculate the time occupied by the muscle in performing a single act of shortening or the twitch. If we compare two types, the one of extreme sluggishness such as the muscle of a tortoise, and the other of extreme activity, such as the wing-muscle of a wasp, we shall find that, whereas the former takes 1.8 seconds to perform a single shortening, the latter takes only 0.009 of a second. In other words, the wasp's muscle "works" two hundred times as rapidly as the tortoise's.

The notion of speed in connection with life is by no means unfamiliar. The common expressions, to live "a fast life" or to find a place "very slow," are not entirely without scientific sanction.

Nature dislikes speed beyond a certain rate and happenings that are too sudden. The nervous system in particular is intolerant, for instance, of loud noises occurring near us with extreme suddenness.

Nature has set limits to the speed of action, to the intensity of livingness. To take a specific case; she has so arranged things that the heart is enabled to go on beating, as we say, "forever," just because it actually rests for a longer period, fourteen hours out of the twenty-four than it works, ten hours.

"It's the pace that kills" is a more appropriate phrase than "burning the candle at both ends." For, though burning the candle at both ends may describe doing without sleep and so depleting the reserves of vital resources, yet the expression, "It's the pace that kills" is a closer description of the anti-vital effects of a "fast" life.

The heat of a fire depends, for one thing, on the *rate* of the draught through it, so too the intensity of livingness depends on the rate at which the chemical and oxidative charges go on in the living substance. These latter can be accurately measured in terms either of the oxygen absorbed or of the carbon dioxide excreted.

When the blacksmith wants a very hot fire, he uses the bellows vigorously for a short time; and when livingness is to be expressed at its maximum of intensity,[1] the tissues receive and dispose of the life-supporting oxygen up to the limit of their respiratory capacity.

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[1] Or potential, to borrow a phrase from the electricians.

The diminution of vitality in a melancholic invalid has its counterpart in the fire that smoulders after the blacksmith has closed down the forge.

This absorption of oxygen is directly proportional to the muscular activity of the animal.

A horse at rest, walking and trotting absorbs per minute 1.6, 4.7 and 8 liters of oxygen, respectively. Therefore, the intensity of its muscular activity is five times greater when trotting than when at rest.

There is nothing new or strange behind this; we often hear it said of some one towards the end of a wasting illness—"he has not much vitality left"; but it is only quite recently that we have contrived to give that "much" or that "little" a quantitative or statistical value.

One is reminded of the man who lost his portmanteau as he was embarking on a Channel steamer; his fellow-travellers crowded round and expressed "*much* sympathy." A Quaker, who had witnessed the accident, stepped forward and said; "I am sorry for you to this extent," and handed him a packet of banknotes.

THE UNFIT SURVIVE

By Dr. HERBERT MAYNARD DIAMOND

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ECONOMIC OBSCURANTISM

WE are not required to theorize very much about the matter of getting a living. We may sit back in our armchairs and speculate as to the influence of the moving pictures upon the morals of young girls and conclude that it is good, bad or indifferent—largely, I imagine, taking the last picture we may have happened to witness as a basis for judgment. Such speculation can not do much harm and is not likely to accomplish much for good; after all, we shall never know just what is the influence of the cinema upon the morals of young girls. On the contrary, however, the farmer does not speculate about the result of using a new fertilizer upon his soil. He puts it to the test and can measure the difference with and without almost to a quarter peck.

Methods and devices utilized in the direct task of getting a living are always capable of similar immediate test; they obtain results, or they do not; schemes and artifices to meet economic ends either succeed or fail. There is a cause and effect relationship here which is rarely obscure. Yet primitive man managed to make the matter of living well very complex, for into it he introduced the element of illusion—of belief in spirits and spiritual agency. His interpretation of life resulted in the incorporation of his religion into his economic outfit. Embracing this additional factor the simple business of getting a living became complicated in manifold ways. Practical observations of results which contact with nature daily afforded him became confused with an unlimited number of theories and notions upon the consequences of spiritual agency. The elements of illusion, of belief in the imaginary environment took, as it were, a place side by side with the realities.

The demands made upon primitive men by the spirit host involved inroads upon their time, energies and resources which, if they had examined the facts solely in the light of immediate material expediency, were plainly of harmful consequence. But believing they were subject to the control of forces which we think to be non-existent they frankly acted upon that premise. The interjection of the philosophy of animism into their interpretation of life experience necessarily modified and complicated savage reactions to economic needs. Our purpose is to ascertain one aspect of the consequences of this additional factor in the economic life of the groups among which it prevailed.

THE BASIS OF WEALTH

All men must work to live; for there is a lack of balance between human needs and available resources; nature of her own efforts does not supply us gratuitously with all the things we need or want. To make up this natural shortage we must apply ourselves to our environment in order to force it to yield more than that which, without our toil, it would freely yield to our use. The effort to live when thus engaged in by human beings becomes what is generically termed industry; food, clothing and shelter and all manner of goods must be provided. The economist calls these goods required for the satisfaction of wants wealth; and to obtain wealth industry is required. Hence, some expenditure of energy is a necessary condition of life for any group of human beings, although such expenditure will vary in intensity as between different groups, owing to environmental variations. The native of the luxuriant tropic may need to make no greater effort for a food supply than to pick and to prepare for eating the fruits of his jungle forest; the Eskimo, at the other extreme, must ceaselessly engage in the toilsome and hazardous chase of the scanty wild life of the ice fields. Yet each in his own way must work.

Among human beings the effort to live is characteristically something more than an effort merely to maintain life. Men try, as the animals do not, not only to live but to live well. Living well, as a formula, has meant accomplishment in two diverse economic directions, namely, more enjoyments and less work. Mankind has always strived to devise means and artifices by which labor might be less arduous; and to improve the quantity and quality of those goods the environment affords.

At base in social evolution,—progress in man's realization of his interests, has been constant advance along economic lines. An economic surplus great enough to release some individuals from the direct toil of material efforts is required to permit the rise and development of literature, art, music and the drama. The clue to the cultural development of a society therefore is likely, if not certainly, to be found in its economic organization. When we study the bearing of the religious beliefs and practices of early men, as it affects their economic welfare, we are hitting at a vital point for this reason; particularly if we may demonstrate that superstition did actually participate in the operation of the more-goods-less-work formula.

THE ECONOMIC ENVIRONMENT

Men's industry is frequently required in the production of benefits which may not be measured by the yard or ton. Before the pioneer could raise his corn, he first set out to clear the forest. Just so, it has been the practice frequently of late years to employ men to float a thin film of oil upon the stagnant marsh waters adjacent to some of the large cities in order to prevent the larvae of the mosquito from developing. Indirectly, the purpose is to prevent the spread of contagious diseases through the medium of the mosquito in these centers of population. Similarly, by preventing the mosquito from breeding yellow fever has been eliminated from former plague-ridden communities; malaria likewise has been brought under control. Although no addition to immediate goods is yielded by these efforts, the results are of inestimable value. Men's labor often, in this wise, works to bring about results, immaterial but calculated nevertheless to make the situation more favorable for the prosecution of their general interests. In this vein we may consider its influence upon primitive industrial and living conditions.

TABOO ON ANIMALS

The taboo of the savage is a spiritual *noli tangere*—a prohibition enforced by the belief that to molest the protected object, animal or persons will result in summary vengeance by an enraged spirit. The taboo takes origin in the notion that the thing tabooed is vested with the interest if not the embodiment of some one of the spirit host. Primitive men viewed that many living creatures either were the resident of some spirit, or that such creatures themselves were essentially supernatural, or that they came under the care and protection of some outside deity or devil. In any case, such creatures were unmolested, decidedly so, from the conviction that the offender by his sacrilege might bring not only upon himself but upon his entire community the wrath of a vengeful demon. How such beliefs were arrived at is largely a matter of speculation; the results of them, however, are not. For it is obvious that so far as these taboos worked out practically, the consequence is direct interference with the operation of the processes of natural selection.

From everything we know of the experience of the human race, it is safe to state that, with the exception of certain insects,[1] and microorganisms, man has proved himself the dominant organism of nature. In the event that men find other creatures either dangerous, destructive or simply noxious and annoying, they may almost without exception clear their immediate environment of such pests and may live in comparative immunity from them. We have not, of course, entirely wiped out such species, but we have driven them to remote places far from the village and the city. When, however, superstition protects the lower organisms men are restrained from behaving naturally toward them and from exerting an altogether natural effort toward the elimination of undesirable and unwelcome neighbors.

SNAKES

Outstanding among such superstitions is the one which protects snakes; early men of many tribes regarded the snake as a creature endowed with particularly supernatural qualities. "The Sea Dyaks would not intentionally kill a cobra for this reason."[2] In India, very remarkable is the effect of such veneration, especially that regarding the cobra. "No orthodox Hindu will ever kill serpents even if bitten, for it is believed that any injury done to them would bring on leprosy, sterility or ophthalmia."[3] "The cobra being an object of worship, it is a deadly sin to kill it."[4] "Though the snakes in this country are noxious to the natives, yet the ancient veneration for them is still maintained. No one dares to injure them or to drive them away by violence; and so audacious do they become that they will sometimes creep between peoples' legs when they are eating and attack their bowls of rice, in which case retreat is necessary until the monsters have satiated themselves and taken their departure."[5] It is related that a certain village in Northern India was not so long ago suddenly deserted by all its inhabitants. No persuasions would induce the people to return, and on inquiry it was found that the panic among the villagers was caused by an unexpected visitation of snakes who had established themselves comfortably in the precincts of the village.[6] In fact, so prevalent is the cobra that it is figured to kill about twenty-five thousand people annually in that country;[7] and in 1904, official records said that sixteen thousand head of cattle were destroyed by this creature.[8]

The veneration and consequent protection to snakes also is found among African groups. The Wakerewe of the Victoria Nyanza region do not kill the gigantic snakes that frequently occur or the other kinds, but look on calmly when these reptiles visit their huts and consider those to be fortunate who are killed by the bite of a poisonous snake.[9] The Kaffirs fear to kill a boa constrictor, and he who happens to do so is forced to spend his waking hours for several weeks lying in a stream of running water to purge himself from his sinful act.[10] And among the Ewe peoples in former times he who killed a python was burned alive for committing so heinous a sacrilege.

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[1] The tsetse fly is one of the outstanding cases of exception; there are also other species, as the boll-weevil, which have baffled the efforts of the entomologists to control.

[2] Roth, "Natives of Sarawak and British North Borneo," I, 390.

[3] Thurston, "Ethnographic Notes in Southern India," 285.

[4] *Idem*, "Omens and Superstitions of Southern India," 124.

[5] Thurston, *op. cit.*, 89.

[6] Monier-Williams, "Brahmanism and Hinduism," 325.

[7] *Ibid.*, 319.

[8] Gregory, Keller and Bishop, "Physical and Commercial Geography," 143.

In America also traces of this ancient superstition are to be found. The Dakotas would not kill a snake;[11] and but few Cherokee would kill a rattlesnake; if they do kill it, they must undergo ceremonies of purification,[12] having exposed themselves to the contagion of spirit wrath—they must undergo prophylaxis. It is safe to conclude that with them also religious sanction was extended to the snake.

The Crocodile

Further evidence of the animal taboo is to be found respecting the crocodile. Crooke in speaking of the veneration for this creature in India remarks, "It is a general rule among savages to spare crocodiles, or rather only to kill them in obedience to the law of blood feud, that is, as a retaliation for the slaughter of men by crocodiles."[13] It has been noted in New Georgia, where the crocodile is taboo, that in the eastern district they may be killed but not eaten; clearly a survival of their one-time immunity. At Rubiana, however, they may not even be touched but "A man of that district whose child had been carried off by a crocodile had the *hopi* (taboo) removed from these creatures, as far as he was concerned, until he had killed a hundred,"[14] evidently in accordance with the law of blood revenge.

The Dyaks afford another illustration of Mr. Crooke's point. For they will not kill crocodiles except in blood revenge.[15] "From superstitious motives, the Dyaks do not interfere with the crocodile until it has developed a man-eating propensity. Then they turn out in a body and make war upon the race and slaughter it wholesale."[16] At the present time, the ancient custom survives in merely symbolic form.[17] On the Lower Niger snakes are "fed and tolerated to such an extent that in those towns in which they are sacred, although they become a pest and even a danger to the people, they are all the more pampered and spoilt."[18] In the town of Brass, the pythons were tended and fed with zealous care by their own especially appointed priests and were never molested or interfered with.[19] As these pythons feed principally on fowls and goats, "it is quite a common event of a morning to find in one hut as many as four or five or even more pythons lying in a semi-comatose condition after having swallowed some of the live stock which they had found on the premises. Unwelcome as the sacred visitors are held on this account, so strict are the rules, so severe are the penalties regarding them that they are left unmolested."[20]

At Bonny, finally, the natives decided to slaughter the iguana "on solid common-sense grounds, for had not the iguana been their mortal enemy for years, by eating their fowls and chickens before their very eyes, thus destroying about the only means a woman of the lower class or one who had ceased to please her lord and master had of making a little pin money.''[21] Very likely it was contact with civilized men which hastened this decision. The natives fully recognized the toll of the taboo. Superstition is not a gratuitous folly. Early men well knew that their immediate interests were hurt; they thought it better policy, however, to bear the loss. Perelaer speaks of this fact also and remarks that with this one exception crocodiles in Dyak land are very much honored and are offered many kinds of sacrifice—hogs, chickens and the like. Such practices, it is said, have hindered the efforts of the Netherland government to root out the species.[22,23]

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[9] Kollmann, "Victoria Nyanza," 135–136.

[10] Frazer, "Golden Bough, Taboo," 221–222.

[11] Spencer, D. S. 4A; 35.

[12] Mooney, "Myths of the Cherokee," *B. A. E.*, 19, I, 294.

[13] "Folklore of Northern India," II, 282.

[14] Summerville, "Ethnography of New Georgia," *J. A. I.*, 26, 386.

[15] Hose and MacDougall, "Men and Animals in Sarowak," *J. A. I.*, 31, 190.

[16] Roth, Nat. "Sarawak," I, 446.

[17] *Ibid.*, 222.

[18] Leonard, "Lower Niger and Its Tribes," 328.

[19] *Ibid.*, 219.

[20] *Ibid.*, 329.

In Madagascar ''the crocodile swims in every river and lake, and from dread of its power the natives will never kill one except in retaliation for one of their friends or neighbors who has been destroyed by a crocodile. They believe that the wanton destruction of one of these reptiles will be followed by the loss of human life in accordance with the principles of lex talionis.''[24] And in Africa, on the Island of Damba in Lake Victoria Nyanza, crocodiles may not be molested and here they become very dangerous to the natives in going upon the water.[25]

Upon this formidable saurian the taboo against killing does not seem to have been so strict as that against the destruction of snakes; nevertheless comparative immunity was afforded it thereby. It was permitted to live and breed near the homes and haunts of men, and by the Dyaks was even pampered and fed. Human life was thus constantly endangered, and travel upon streams and near their banks made precarious.

THE FELINES

The great felines, the tiger, the leopard and the lion, were similarly venerated by many primitive peoples. In North India, the tiger is held sacred by the Kisans and the Santals, who never kill such an animal. They believe that in return for such devotion the tiger will spare them.[26] In Africa native behavior indicates this taboo to have been a feature of the customs of past times. Among the Ewe a man who kills a leopard is theoretically put to death; but really the culprit escapes by paying a fine and by performing propitiatory ceremonies. Among them no leopard skin may be exposed to public view.[27] The Kaffirs and the Hottentots both seem to regard the killing of a lion as morally unclean and isolate and purify the lion-killer.[28] The natives of the Loango Coast after killing a leopard hold a public ceremony in which they publicly apologize to him for having been so rude as to kill him.[29] Clearly we may see in this the carrying over of past actuality into a present formality. The group discontinuing a former practice retains the form but abandons the substance.

In Livingstone's account of the territory through which he traveled, the original situation still obtained; he said, ''There are also a great many lions and hyenas and there is no check on the former, for the people believing that the souls of their chiefs enter into them never attempt to kill them.''[30] At one time therefore there unquestionably existed in Africa a widespread taboo affording protection from molestation to these dangerous and destructive animals.

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[21] DeCardi (in Kingsley's W. Aft. St.), 314.

[22] Perelaer, ''Ethnographische Beschrijving der Dajaks,'' 7.

[23] Perhan, ''Sea Dyak Religion,'' *J. R. A. S. St. Br.*, 14.

[24] Sibree, ''Great African Island,'' 269.

[25] Roscoe, ''The Baganda,'' *J. A. I.*, 32, 6.

[26] Crooke, ''Folklore of Northern India,'' II, 218.

[27] Ellis, ''Ewe Speaking Peoples,'' 74.

[28] Frazer, ''Golden Bough, Taboo,'' 220.

[29] Bastian, ''Die Deutsche Expedition an der Loango-Kuste,'' I, 243.

[30] Spencer, ''Principles of Sociology,'' I, 330.

However, so far as Africa is concerned, we must base our judgment almost entirely upon illustration from social survival, that is to say, the preservation in present social practice of ancient customs in form rather than in actuality. This is of course a commonplace element in social evolution. We see it in the chocolate Easter egg. There is, however, in the case of felines a tendency in the direction of modification of socially disadvantageous practices. Such changes came but slowly in the passage of time, gradually passing the original expensive and harmful custom into one of formality and safety. The earlier demand of superstition is met by a form rather than by a fact.

Birds

Religious protection extends similarly to the feathered creatures. The Kenyahs of Sarowak will not kill a hawk. The writer tells us, however, that "they would not prevent us from shooting one if it stole their chickens."[31] They were aware of the cost of the taboo on the hawk, but they dared not themselves to kill it. The Mongols permit crows to perch on top of loaded camels and to steal mutton before their very eyes. Hawks swoop down in the market place at Urga and snatch eatables from the hands of the unwary.[32] Among some South African tribes "the eagle is sacred and is never killed . . . though it carries away large numbers of domestic chickens and often kills young lambs and kids."[33] In Coomassi the Tshi allow vultures to fly in hundreds untouched, and they are so bold as to pounce upon fish or meat carried on the head.[34] Even a taboo on birds may be fraught with distinct disadvantages.

Other Creatures

Among the Dusuns the rats destroy the crops but are not molested.[35] The rat in North India is also very sacred and may not be killed and becomes a great household pest.[36] In the light of our present knowledge of the rat as a disease-carrier, we may appreciate the potential menace of this superstition to human interests.

The bear is an object of like veneration; in North India some groups refuse to kill it. The Crow Indians of America would neither hunt nor trap a bear; they believe it bad luck and will not touch the food.[37] In this case the result is to refuse a source of food supply.

In Burma even hardened convicts will not harm the vermin that infest their mattresses. Shway Yoe remarks, "A story is told of a man who allowed the snake who killed his father to wriggle away unmolested"; and he continues, "I myself have seen a Burmese mother take up between two bits of bamboo the scorpion that had stung her little son, and simply throw the hideous creature out of the window."[38] Such actions are dictated by the Buddhist injunction against killing.

Monkeys are a source of great annoyance and are protected in the same way from human interference. In Sarowak the *dok* (macacus nemestrinus) or the cocoanut monkey is very common and they will kill it only when stealing their crops. "The *dok* does not help them in any way but only spoils their crops."[39] Here, again, a grain of common sense tempers the taboo. The religious injunction is not sufficiently binding to protect the malefactor if caught in the act. In parts of India likewise the monkey is sacred; "often a troop will make its appearance in an Indian village, tear off the roof of a native house and do even worse damage out of sheer wantonness, yet no householder would ever dream of reprisals. The sacred character of the monkey shields him from all harm."[40]

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[31] Hose and MacDougall, *op. cit.*, *J. A. I.*, 31, 178–179.

[32] Gilmour, "Among the Mongols," 235.

[33] MacDonald, "South African Tribes," *J. A. I.*, 20; 115.

[34] Ellis, A. B., "Tshi Speaking Peoples," 213–214.

[35] Roth, H. L., "Nat. Sarawak," I, 403.

[36] Crooke, "Folklore of Northern India," II, 241–2.

[37] Jenks, "Faith in the Economic Life of the Amerind," *Am. Anth. N. S.*, 2; 681.

[38] Shway Yoe, "The Burman," II, 40.

The unfit survive. Men die that snakes may live—an outrageous inversion of the operation of natural selection. Man's unique privilege of rationalization brought him to the belief in spirits; the belief in spirits, in turn, led him to endow creatures, far below him in the evolutive scale, with powers far above his own—as he viewed the matter—in the spiritual scale. Forbidden, then, to exercise his natural advantages in warring on his enemies, idly he sat by viewing the toll of death and destruction with complacent faith,—his spirits had so decreed.

When we consider the fact that this condition obtained among men of the lowest culture we may the more accurately estimate the monstrous cost. Such men, at best, had but a tenuous grip on life; their knowledge of the industrial arts was rudimentary, their resources meager and uncertain. Indeed, so heavy was the burden of maintaining life that among themselves natural selection operated inevitably and ruthlessly. The old, the crippled and the blind, because they could not fend for themselves, slowly died for want of care, were killed outright by compassionate relatives or were abandoned; the productive had no surplus to share with the non-productive. Yet the tiger, the crocodile and the rat lived, and, if need be, at the expense of an always impoverished humanity. Had these men regarded their noxious neighbors solely as physical in attribute, conquest would have been quick and decisive; regarding them, however, as supernatural in endowment, the war decreed by the dictates of nature was delayed at behest of imaginary powers. To what extent human progress was delayed by the perversion we can not state; it suffices, however, to note the retarding pressure of this cult.

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[39] Hose and MacDougall, *op. cit., J. A. I.*, 31, 191.

[40] Monier-Williams, *op. cit.*, 222.

SCIENCE AND RELIGION

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To insure the rapid extension of man's reign over his empire, science and religion must somehow be brought to terms. An unfriendly relationship between these factors of social change means necessarily something less than the maximum of effort and achievement in promoting the well-being of mankind. There is nothing at present more desirable than the cooperation of science and religion in the promotion of human progress. I purpose, then, to discuss some of the proposed methods of reconciling science and religion, and to point out and elucidate a mode of reconciliation that would call for no diminution of the enthusiasm and efficiency of either. First, let us consider the differences existing between science and religion, if any, with regard to the nature of truth, its value and the methods of its discovery.

TRUTH AND ITS DISCOVERY

Truth is commonly defined as a harmony, agreement or correspondence between our thought and reality; that is, between our thinking and the things we think about. Both science and religion accept this view of truth. They agree, too, in the conviction that a knowledge of the truth is valuable. Knowledge, it is said, is power; and power is in itself something to be desired. It is a plain fact that man's power of achievement has advanced with the advancement of his knowledge. So, too, it is recognized everywhere, and by all who have given the matter a moment's thought, that truth and knowledge are valuable as a guide to action. Blind action may be effective, but in changing conditions it is not as likely to be so as action that is intelligently directed. And, finally, both science and religion are equally convinced that the truth is valuable as a promoter of intellectual freedom, and such freedom, at least in the abstract, is regarded as something to be desired.

Both science and religion, then, profess unqualified respect for the truth. Both regard it as socially serviceable, and quote with equal approval the saying of Jesus, "Ye shall know the truth, and the truth shall make you free." So far, then, there is no conflict between science and religion, if both are sincere in what they profess. Disharmony between them arises, however, in regard to the most reliable source of truth, and the best method of finding it out. There have been, and are, various ideas on this important point. Some of these we shall now consider.

We need hardly be detained by the all too prevalent conception that truth, at least particular truths, may be ascertained by various forms of hocus-pocus. Primitive man reposed great confidence in magic, in the divination of truth by observing the flight of birds or investigating the condition of their entrails; in oracular pronouncements of supposedly inspired persons; in dreams, signs, etc. Unfortunately, there are many now, even among those supposed to be educated, who expect to find truth in similar fashion—star-gazing, fortune-telling, card-shuffling, the ouija board, the chance arrangement of coffee grounds, and the like. All such "vestigial remains" of primitive beliefs should have no place either in science or religion. We turn to methods more deserving of attention.

It is sometimes said that truth is

intuitively perceived, intuition being regarded as independent of the reasoning process. It is probably the fundamental element in that process. Anyhow, it is safe to say that the science of psychology does not regard intuition as outside the field of natural psychic phenomena, and will explain it, or attempt to explain it, as a natural result of individual or of racial experience, or of both. Moreover, no psychologist would contend that what we call intuition is always safely reliable, or that it serves as a guide, except within very narrow limits. It is not likely, then, that intuition will ever be regarded by the most careful seekers after truth as an effective and reliable means of obtaining it. Science and religion are not divided on this ground.

Again, there are those, particularly in oriental countries, who argue that truth is to be gained by a method quite as economical of effort as is the method of intuition, namely, by passive reflection, by meditation; in short, by assuming a certain attitude. Truth, they hold, is an emanation from the divine mind. The mind of man, being in reality a part of the divine mind, may receive truth as an influx, providing he puts himself in a properly receptive attitude. The attitude to be preferred is apparently one of perfect mental passivity. It is sometimes called putting oneself "in tune with the Infinite." The most effective procedure, they say, is to "retire to the silence," and restrain as nearly as possible all mental activity. Truth will then steal into the mind. Emerson, who was himself something of an oriental, gave currency to this view by his doctrine of the oversoul. According to his teaching, the minds of men are but the organs of a mysterious entity called the oversoul. Or they are the harps which, when properly attuned to the divine mind, give off a music apparently their own, though the vibrations are produced, so to speak, by a breeze from the Infinite. At any rate, truth is an influx of the divine mind, and may be had by any one who reverently listens. It was so the prophets glimpsed the truth.

> The word unto the prophet spoken
> Was writ on tables yet unbroken;
> The word by seers and sybils told
> In groves of oak or fanes of gold,
> Still floats upon the morning wind,
> Still whispers to the willing mind.[1]

Since the mind appears to be always active, even in sleep, complete mental passivity is a condition difficult, if not impossible, to attain. Ideas do come and go in a manner which psychology does not as yet profess to explain, but there can be no question that some of these ideas that so mysteriously enter the mind are anything but truth. For this reason it must always be necessary to subject ideas flowing into the mind to a critical examination in order to determine their validity and to estimate their value. At any rate, science and religion are never likely to get together on the ground that truth enters when the gates of the mind are properly opened, or that it surrounds the mind as the atmosphere the body, and is to be taken in by a process involving a less expenditure of energy than does the act of breathing. Mental activity, rather than passivity, is the safer prescription for successful approach to the truth.

While it may well be admitted that meditation and reflection should be practiced, particularly in the western world, much more than they are, they can not be regarded as an exclusive or superior method of truth-seeking, or as giving validity to the doctrine that truth and knowledge have their source in the divine mind and are diffused by a process similar to radio transmission.

Science and Revelation

We come now to a view of truth and a method of ascertaining it, concerning which science and religion are definitely, and perhaps irreconcilably, at war. It is the view or idea that Omniscience, the possessor of all truth, has once for all revealed to mankind all we need to know, through chosen representatives who were specially inspired. The idea of inspiration is, of course, as old as the belief in disembodied spirits. It was held by primitive men as one of the fundamental ideas of their philosophy. In primitive times, however, good and bad spirits alike were supposed to speak by inspiration. But the belief now entertained by religion almost the world over is that God, himself, has employed inspiration to reveal the truth to man, which truth is embodied in sacred documents—"sacred books," as they are called, such as the Rigveda of the Hindoos, the Zend-Avesta of the Zoroastrians, the Koran of the Mahommedans, etc., and the Bible of Christian nations. Each of these books, it is maintained by their respective "defenders," "is given by inspiration of God, and is profitable for doctrine, for reproof, for instruction in righteousness." The followers of each religion often go so far as to maintain that their own sacred book contains all truth; that other books, and of course scientific inquiry, are unnecessary. The Caliph Omar is reputed to have said of the seven hundred thousand manuscripts in the Alexandrian Library, "If they agree with the Koran, they are useless; if they disagree, they should be destroyed." And St. Augustine laid down the law concerning our Bible which many apparently accept to-day: "Nothing is to be accepted save on the authority of Scripture, since greater is that authority than all the powers of the human mind."

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[1] Emerson, R. W., "The Problem," Complete Works, Concord Edition, Vol. 9, p. 8.

But, without denying great value to the so-called sacred books of the world, there is an increasing number of people who are coming to believe that their value lies not in their mysterious inspiration but in the fact that they are records of the evolution of man's conceptions—particularly his religious conceptions, beliefs and aspirations. This is the view that science accepts. It was well expressed by Andrew D. White, who said: "The inestimable value of the great sacred books of the world is found in their revelation of the steady striving of our race after higher conceptions, beliefs, and aspirations, both in morals and religion. Unfolding and exhibiting this long-continued effort, each of the great sacred books of the world is precious, and all, in the highest sense, are true. Not one of them, indeed, conforms to the measure of what mankind has now reached in historical and scientific truth; to make a claim to such conformity is folly, for it simply exposes those who make it and the books for which it is made to loss of their just influence."[2] Thus, while these books may still be regarded as revelations, as science itself is a revelation, "revelation" in the earlier sense is no longer applicable. Indeed, it would perhaps be better not to employ the word at all, for most people have the old idea, and are thus brought in conflict with the scientist who finds in the doctrine of inspiration one of the chief enemies of his disposition to inquire and to explore.

Of course, the idea of revelation, as usually entertained, has been given up, wholly or in part, by many who regard themselves as religious. It is certainly not held by some of the more advanced thinkers of the church, and as a rule it is not admitted by those who cultivate science. Still it is prevalent throughout Christendom. Indeed, it is hardly too much to say that science and religion, on this doctrine of a divine revelation, as ordinarily conceived, are diametrically opposed. The very beginning of scientific thought and activity, prompted by doubt and curiosity, implied a disbelief in revelation, and the growth of science has certainly been away from the idea. Indeed, it must flatly reject it, since it is plainly derived from the primitive man's very natural but erroneous belief in possession. In so far, then, as religion clings to the doctrine of revelation, there would seem to be no reconciliation between it and science. This entire idea, however, may best be considered by a frank discussion of the relation of science and the Bible.

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[2] White, A. D., "A History of the Warfare of Science with Theology in Christendom," Volume 1, p. 23.

Science and the Bible

As everybody knows, the Bible was long regarded, and is now regarded by millions of people, as the exact and infallible Word of God. They suppose it to have been transmitted through its reputed authors, and, according to many, without error in its transmission. It is the view of the "fundamentalist," as I understand it, that it is divinely inspired in its minutest particulars. No wonder, then, that it is regarded by him not merely as *an* infallible source of truth but *the* infallible source of all truth, or at least of all truth that it is necessary for man to know. It is a consistent view. If it is the "Word of God," the very words of his mouth, it must be strictly true, since it is "impossible for God to lie," or, if omniscient, to be mistaken. Every statement in it, then, must be literally, historically and scientifically correct. From it may be constructed, not only a history of the world, but a cosmology, a geography, a biology, an anthropology, etc. True science, then, must be derived from a study of the Bible, anything else pretending to be scientific is "science falsely so-called." Clearly, if this is the case, the investigations of the scientist are unnecessary or they are impious.

This being the view, long entertained by the church, we can easily understand why, in the early history of science, there was so bitter a conflict between science and religion. The pursuit of scientific knowledge was opposed to the fundamental idea of the church, and the church could not fail to recognize it. It undertook, therefore, to destroy science, and failed. Science has destroyed one by one the survivals of primitive thought in religion, but has thus far failed to eliminate the survival contained in the idea of a Divine revelation. Have we here, then, the ground of a perpetual conflict between science and religion? Or, can it be removed?

As already said, there are many, both in religion and in science, who have solved the difficulty in a manner satisfactory to their own minds. They believe themselves able to "reconcile" the Bible and science, or they have accepted the view that religion is not concerned with scientific truth, or *vice versa.* But it is a plain fact that millions still adhere strictly to the idea that the Bible is an infallible source of truth, even in the particular field that science claims as its own, that is, the field of the so-called natural sciences. It should also be plain that this idea is indefensible, and is doomed to obsolescence and final disappearance.

Obsolescence, I say, for ideas do not die suddenly and disappear at a given moment; they are supplanted or transformed. Many who have frankly surrendered the extreme idea of biblical inspiration still entertain an elastic conception of it; inspiration "with limited liability," as some one has said. The Bible is inspired, they say, it is truly the Word of God, but it is couched in such language and employs such images as the minds of the people of the time in which it was written could understand. Why it should have been adapted to the understanding of men in an earlier stage of civilization, and to the mystification of the men of to-day, it is difficult to comprehend. But anyhow, the Bible, they say, is true, and in so far as science is true there can be no conflict. Anything that appears to them to conflict with the divine truth of the Bible will be regarded as irreconcilable, and so there will be perpetual cause of conflict. Since it is easier to deny than to reexamine, there must be constant demands for adjustment, and always disputation in regard to who should make it. Unless the truths of science are apparently in harmony with biblical texts as commonly interpreted, the former will always be regarded, as I have said, as "science falsely so-called." From the beginning of science, the usual procedure has been: first, a proclaimed discovery of scientific truth, then a flat denial on the part of religion; the truth involved is plainly in conflict with the Bible, and there is a great flourish of texts to prove it. Failure so to do is at length followed by the declaration that the Bible teaches it, and thus a compromise is effected by far-fetched reconciliations of textual statements with ascertained facts.

Now it looks, to an impartial observer of the existing situation, that any attempt to reconcile science and the Bible in the field of the natural sciences is futile, a mere waste of energy. There is no such reconciliation.

As an example illustrative of the futility of spending time and thought in an effort to reconcile science and the Bible, let us glance at the first chapter of Genesis. Let us read a portion of that chapter, interjecting here and there such comments as we might reasonably expect a reader fairly well informed in science to make who was reading that chapter for the first time, and who had been told that it is a scientific account of creation.

> In the beginning [a beginning is inconceivable] God created [out of nothing?] the Heaven [that "undiscovered country"] and the Earth. And the Earth was without form [impossible] and void [void of what?]: and darkness was upon the face of the deep [How could there be a "deep," if the earth was without form and void?]. . . . And God said, "Let there be light [Light without a sun!]; . . . and God divided the light from the darkness [evidently they are supposed to be material things!]. . . . And the evening and the morning were the first day [and as yet no sun!]. And God said, Let there be a firmament in the midst of the waters [evidently the firmament, that is, the sky, is supposed to be a material thing!].

And so on. How much credence would such a reader give to the chapter as "a scientific document"? Evidently none at all. Let him read it as a poetical conception of an early writer, and the effect would be different.

Is it not clear, then, that it would hardly occur to an impartial reader, either to accept the first chapters of Genesis as a scientific account of creation, or to suppose it possible to reconcile the account there given with the findings of modern science? So with the Bible as a whole, science can not accept its crude and naïve explanations of natural events, as a literal account of the facts. Science knows that all these biblical stories are derived from conceptions long antedating the appearance of the Bible, many of them, in the main, identical with stories found in the mythology of heathen nations. The Bible, therefore, whatever else it may be, never can be regarded by science as an infallible source of the truths that men are seeking in the field of nature, and many of the most religious men of to-day concede that science is right.

But there are even scientists who, perhaps because their interest does not extend beyond the study of material things, or because they are over-zealous for peace, are willing to concede the claim of many theologians who have themselves given up the infallibility of the Bible with respect to natural science, that the Bible is an infallible source of truth with respect to religion and morality; it is "an infallible guide to faith and practice," they say, to quote the usual form of expression. But as science extends itself into the field of morals, as it is now doing and will do more and more, this claim too will be rejected. The evolution of morals is as plain to the student of the evolution of society as is the evolution of the material world; and morality, which necessarily involves conduct, needs the assistance of science in its direction, as does any other form of activity. We need and must have a scientific ethics. Science is bound to extend its area to include the study of all social phenomena; it is bound to lay claim to the entire field of phenomena, the phenomena of mind and morals, conduct and religion, as well as the so-called phenomena of nature—to spiritual phenomena as well as material phenomena. In a word, science claims, or should claim, for its subject-matter the entire realm of the knowable; and the admission of infallibility with respect to knowledge in the field of morals, or of infallibility, anywhere or at any time or upon any subject, is fatal to the full development of science and its potential social beneficence.

Is this to be regarded as a rejection of the Bible? Many will think so. They will regard the admission that the ancient literature contained in the Bible has no more claim to infallibility than any other ancient literature as what they call its "rejection." It is rather to be considered as a rejection of certain ideas concerning the Bible. Science no more "rejects" the Bible than it does any other piece or collection of literature. Rejection is not the word for it; the word is used, one feels, because to many minds it carries a suggestion of moral deflection. It is more impressive and condemnatory to say of science that it rejects the Bible than it is to say that science rejects "my view" of the Bible. If the Bible itself pretended to be a scientifically accurate description of the events it describes, science would most assuredly reject its pretentions. But it does not, and so science is obliged to reject the pretentions of those who claim infallibility for it; as it does and must the claim of any authority to inerrancy and infallibility. Science, indeed, knows nothing of either the one or the other.

Science, as I have said, claims or should claim the entire realm of the knowable. In its beginnings it looked out upon this realm with a conception of its own ignorance. It discovered that the mind of man, by the application of a certain method of its own devising, is capable of dispelling this ignorance. It, therefore, set to work and, by systematic application of its method and strict adherence to it, sought to extend the area of knowledge. It has done so. But in doing so, it has met continually the opposition of those who contend that true knowledge may be acquired by more easy-going methods—by the methods I have already mentioned: by passive contemplation, by consulting oracles, by divination, by casting lots, by star gazing and a thousand and one other modes of arriving at the truth without the trouble of patiently assembling and studying the facts and drawing valid inferences from them. All such methods it brushes aside. It meets the contention that the so-called sacred books of the world, or some particular one of them, contain a divine revelation of the truth, making it unnecessary to explore, to investigate and to reason from established facts. True to its method, it proceeds to study these books in exactly the same manner in which it studies other phenomena. The so-called higher criticism of the Bible, for instance, is nothing else and nothing more than the application to its study of the spirit and methods of modern science. It has reached the conclusion, at least on the part of many of its devotees, that there is no book in the world that does not contain error, and the Bible is no exception. It also admits that there is none of the sacred books of the world that does not contain much truth. But it accepts no book as a final authority. Its final appeal is to facts, always to facts. It has constructed a method of investigating facts, and a logic of thence deriving laws and principles. On these it must rely. Science must go "on its own."

This does not express the view of all scientists. Some, there are, who seem to think, even assert, that the scientific method is not the only method of ascertaining truth, and they point to the method of experience. But in so far as experience discloses truth, it must be reckoned as a part of the scientific method.

Science, then, if and whenever it

manifests a disposition to take short cuts to the truth, or to take possession of it without the toil of investigation, will always be thrown back upon its fundamental and approved assumption that knowledge is to be gained only by the exercise of the mind in the investigation, by the most reliable method, of the facts of nature and reasoning from these facts as a basis. "The free employment of reason, in accordance with scientific method," said Huxley, "is the sole method of reaching truth." If labor is a curse, as it is not necessarily, then indeed is there a curse on science, for only in the sweat of its face shall it eat the bread of truth.

In concluding this aspect of our subject, we may repeat that science does not, and from its very nature can not, admit that either the Bible or any other book is inspired in the sense of being dictated by Omniscience, nor will it recognize the existence of a divine revelation as claimed by the church. There is, therefore, no possible reconciliation of science and religion on this ground. It should be recognized, once for all, that to this it must finally come, that theories of inspiration implying infallibility in anything belong to the childhood of the race and can never be accepted by science.

Science and Religion as Different Realms

There is, however, another species of attempted reconciliation between science and religion which must now engage our attention. It is found in the idea that science and religion are concerned with different kinds of truth, that they occupy different realms, and that there is, therefore, no necessity of any conflict between them. They are to be reconciled by dividing the universe and allotting to each its part. Religion, it is said, is concerned with only transcendental conceptions, God and man's relation to Him, for instance; while science is interested only in material phenomena. It explains such phenomena by reducing them to natural causation; but religion seeks final explanations; that is to say, science deals only with secondary causes, while religion deals with final causes. Religion, therefore, should leave the field of natural causation to science, and science should not interfere with religion in its speculations concerning God and man's relation to Him. Thus a *modus vivendi* between them is to be established by a sort of truce; they are to agree to let each other alone.

The classical example of this sort of attempted reconciliation is that presented by Herbert Spencer in the early chapters of his "Synthetic Philosophy." It is briefly as follows.

Religion is primarily concerned with the cause behind phenomena. From the beginning, however, it has professed to know the nature of this cause, interpreting it in terms of human personality. All gods have by it been represented as manlike, anthropomorphic. In so far as it has claimed positive knowledge, it has trespassed upon the province of science. Science has compelled it to give up one after another of its dogmas, and will continue so to do until its idea of the first cause is shorn of its anthropomorphic attributes, and yet its primal assumption remains as a necessary element in the human consciousness. Religion is thus reduced by Spencer to the consciousness of a mystery behind phenomena which the human mind is not able and never can be able to solve.

On the other hand, science, which limits itself to the field of phenomena, is equally compelled to recognize that all its facts and all scientific knowledge merge into the inconceivable or unthinkable, the postulate of religion. It is bound to recognize that all its explanations are approximate and relative. It can offer no final explanation of anything more than can religion. When science becomes fully convinced that its explanations are approximate and relative, that all its facts are in their ultimate genesis unaccountable and supernatural, and when religion becomes fully convinced that the mystery it contemplates is ultimate and absolute, then, according to Spencer, a permanent peace between religion and science will be established. "Religion," he says, "has, from the first, struggled to unite more or less science with its nescience; science has, from the first, kept hold of more or less nescience as though it were a part of science. Each has been obliged, gradually, to relinquish that territory which it wrongly claimed, while it has gained from the other that to which it had a right; and the antagonism between them has been an inevitable accompaniment of this process." This antagonism will continue, he thought, until each fully recognizes its rightful limits. Or, to put the matter in another way, science as well as religion involves a consciousness of an incomprehensible power, an infinite and eternal energy called omnipotent from our inability to assign its limits, the consciousness of which is common to both, but the nature and attributes of which are incomprehensible to our finite minds. Thus both science and religion are reducible to a single form of consciousness. Consciousness, under one aspect, constitutes science; under another aspect it constitutes religion. Both are thus concerned with different spheres. Let religion confine itself to its proper sphere, namely, the supernatural, and science to the realm of natural phenomena and all will be well.

This form of reconciliation, as Ward remarked, "vividly recalls the manner in which the man is credited in the story when dividing his house with his wife, taking the inside for his portion, and allotting the outside to her!"[3] It is not probable that religion will be content with this division. There is plenty of room on the outside, but not much to challenge profitable thought; for in that ethereal region nothing, according to Spencer, can positively be known. Speculation alone is left to religion.

Notwithstanding the fact, then, that from Spencer's viewpoint religion and science are necessarily correlatives, standing for antithetical modes of consciousness that can not exist asunder, and notwithstanding the fact that it gives religious sentiment the widest possible sphere of action, there is not any likelihood of a reconciliation unless religion is brought back inside the house and the interests of both are united. This, I believe, can be done.

SCIENCE AND RELIGION DEFINED

Before attempting to suggest how it can be done, let us take a glance at the essential nature of science and religion.

Science is concerned with knowledge—all knowledge. It is usually defined as tested knowledge which, in the various sciences, comes to be organized, classified and used for further discovery. Naturally the conception of science includes the method employed as well as the results. We properly speak of "the scientific method." There are, however, two prevalent misconceptions of science. They concern both its results and its scope. In the first place, since the aim of science is truth, that is, exact correspondence of scientific statements with reality, it is often spoken of as if it had attained this aim, that is, that at least in certain sciences we have accumulated a body of knowledge that is exact. We have what are called "the exact sciences." And so it is by some assumed that science in general is a body of truth that is fixed, established and unchangeable. This, however, is an error. It exceeds the claim of science. There is, in fact, no such thing as an "exact science," in the precise meaning of that term. Sciences have attained different degrees of exactitude in proportion to the complexity of the facts with which they deal. Some are more exact than others, but none of them is warranted in claiming for its pronouncements more than approximations to the truth. In physics, for example, scientific conceptions of the atom have had to be revised, and will perhaps be revised again. Mathematics, the most exact of all the sciences, finds itself contemplating a necessary adjustment to new theories of time and space. Every truth of science must be held subject to modification by new and wider generalizations. Those who desire absolute certainty will be disappointed if they turn to science. Indeed, disappointment must be their fate wherever they turn. For, in a universe that stretches into the infinite, there can be no such thing as a complete body of truth that is fixed and unchangeable. Infallibility when claimed for science is just as objectionable as infallibility claimed for religion. Once more, and now in the language of Huxley, "of infallibility, in all shapes, lay or clerical, it is needful to iterate with more than Catonic pertinacity, *Delenda est.*" Science is always changing, adapting and growing. It is knowledge and a particular method of ascertaining it. In the various sciences it presents bodies of knowledge as nearly exact as men have thus far been able to make them by a method of investigation as nearly perfect as man has thus far been able to devise. Its results, however, should always be regarded as more or less tentative, more or less imperfect, and more or less symbolic.

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[3] "Dynamic Sociology," Volume 1, p. 156.

The second misconception in regard to science, and it appears to be entertained by some scientists themselves, is that science is concerned only with so-called material phenomena. At first it was supposed to be limited to the study of physical phenomena. Its field has been extended, rather slowly and grudgingly, to biological and psychological phenomena. Only recently, and still more slowly and grudgingly, has it been extended to social phenomena. But it ought to be obvious that science is equally concerned with all these fields, and not merely with a description of the facts there found, but also with the relations and interpretation of these facts as well; not merely with laws and principles, but with the observation of laws and the application of principles. In its higher generalizations, it is sometimes called philosophy, but it is "scientific philosophy," and differs from metaphysics in that it confines itself to the knowable. Social phenomena, then, social relations, right conduct, the good life and the relation of accurate knowledge thereto, all values and ideals so far as they have a social reference, are properly subjects of scientific study, just as legitimately so as atoms and molecules, the earth and the stars. Since morals obviously have, and religion quite as obviously may have, a social reference, morals and religious values and ideals, their origin, development and validity, should also be regarded as the subject of scientific study and of scientific evaluation. There is, perhaps, no greater social need to-day than that science should be extended to its legitimate limits, namely, to everything that can be known.

Religion, on the other hand, is not so much concerned, or at least not primarily so much concerned, with knowledge as with desire. Science is knowledge, religion is an attitude. I have defined religion as "the effective desire to be in right relations with the Power manifesting itself in the Universe."[4] It had its origin in the desire of the primitive man to be in right relations with mysterious powers whose existence he wrongly inferred from the phenomena of nature. Very early he was led to the belief that these powers were the dead who still lived on in the form of ghosts. The ghost of his ruler became his God. By a natural process, well understood by students of comparative religion, his gods were integrated, and polytheism became monotheism. Conceptions with regard to the nature and attributes of God have undergone a gradual process of evolution, also well known by all students of the history of thought. In every stage down to the present such conceptions have been anthropomorphic. At first, and quite naturally, very low qualities were attributed to the Deity. The conception depended upon the character of the people who entertained it. To-day, with many people, all these anthropomorphic conceptions are unsatisfactory and have been given up. We hear, now, of an immanent God, although this conception is rightly regarded as vague. The terminus of this evolution of man's conception of God has been indicated both in science and religion, namely, the consciousness of a power manifesting itself in the universe, but so far transcending man's knowledge that it is forever beyond his comprehension. He can not be sure whether it is personal or impersonal and, as Spencer remarked, he has not to choose between the two; it may be superpersonal.

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[4] "Work and Life," New York, 1913, p. 264.

> Is it not just possible [he says] that there is a mode of being as much transcending intelligence and will, as these transcend mechanical motion? It is true that we are totally unable to conceive any such higher mode of being. But this is not a reason for questioning its existence; it is rather the reverse. Have we not seen how utterly incompetent our minds are to form even an approach to a conception of that which underlies all phenomena? Is it not proved that this incompetency is the incompetency of the conditioned to grasp the unconditioned? Does it not follow that the ultimate cause can not in any respect be conceived by us because it is in every respect greater than can be conceived? And may we not therefore rightly refrain from assigning to it any attributes whatever, on the ground that such attributes, derived as they must be from our own natures, are not elevations but degradations?[5]

When the truth is perceived that God is incomprehensible and that man's speculations with regard to his relation to God must necessarily remain speculations, it will also be perceived that religion may properly be defined as the desire to be in right relations with the highest ethical conception of human life, a conception that can be determined by science as applied to the study of individual and social phenomena. Science may, and will, substitute for vague and always unverifiable ideas of the power behind phenomena, as a criterion for right action, a thoroughly reliable scientific conception of the social conditions necessary to the highest development of man's personality and his happiness. The effective desire for such conditions must necessarily generate a desire for the knowledge necessary to realize them; and since the scientist, like every one else, may be expected to have some interest in his own happiness, only to be attained by the application of science, he will be equally interested in assuming and in promoting the personal attitude by which alone it may be reached. Desire and knowledge will function to a common end.

A Suggested Reconciliation

Suppose, then, that religion should abandon the idea of a divine revelation of the truths of science, and of the possibility of comprehending the Infinite, as it will be obliged to do; and suppose that the field of science is extended to cover the entire realm of phenomena, including the social, moral and religious, as well as material phenomena; and suppose further that upon the basis of a scientific knowledge of the materials and forces of nature and the possibilities of achievement, a social ideal should be scientifically constructed. Now, since religion is professedly interested in the realization of the Kingdom of God, that is, an ideal society, it will see the necessity of scientific knowledge as a means of effort in its attempt to realize that ideal. As a matter of self-interest, it will offer every possible encouragement to scientific investigation in every possible field. Religion will thus become scientific.

On the other hand, if science recognizes, what is plainly the truth, that it

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[5] Spencer's "Synthetic Philosophy," "First Principles," Vol. 1, p. 109.

is concerned or should be concerned not alone with material phenomena, the field of so-called natural science, but the realm of so-called spiritual phenomena as well, that is, the phenomena of morals, religion, ideals, values, etc., then it must also perceive that its work is not complete when by means of the scientific method it has discovered a fact, a law, or a principle; but that it must manifest an interest in the practical, that is, scientific, application of these discoveries in the construction of an improved society. Science and religion, then, interested in a common purpose and each being dependent upon the other for the realization of that purpose, their reconciliation must obviously come about. Thus science becomes religious and religion becomes scientific. This brings the two together in a common aspiration, a common interest, and a common effort. They cooperate rather than compete.

CONCLUSION

If it be said that this is religion without a God or the Bible, I should not feel obliged to admit the contention, although a religion without a God is not merely conceivable but is a fact, as in the case of Buddhism. But what is here proposed merely means that both science and religion shall agree upon the idea that the cause behind phenomena is incomprehensible. They do, in fact, agree upon this point. "Canst thou by searching find out God?" Furthermore, that they agree, God or no God, that human happiness is the end to be attained; and that they perceive, as they must perceive, that, in any effort to reach the end, science is helpless without religion, and religion is helpless without science. They must function together—ideally, of course, in the same personality. This leaves scientist and religionist to speculate to their heart's content about the nature of the great cause, the ultimate nature of reality, the ultimate meaning of life, etc., but the immediate concern of each will be the scientific organization of human effort to promote the advancement of society in the direction of a scientifically constructed social ideal. This will be their religion. "That a man should determine to devote himself to the service of humanity," said Huxley—"including intellectual and moral self-culture under that name; that this should be, in the proper sense of the word, his religion—is not only intelligible, but, I think, a laudable resolution." And he adds that he is "greatly disposed to believe that it is the only religion which will prove itself unassailably acceptable so long as the human race endures."[6]

As for the Bible, as I have already shown, there need be no more thought of discarding it than of discarding any other great human document in which ideas and ideals are set forth. Nor need we fear the loss of a single truth it contains.

> One accent of the Holy Ghost
> The heedless world hath never lost.

But, at any rate, you say, this means a religion without the ordinary or orthodox conception of God and of the Bible. Be it so, a religion which will really unite all men in the service of the ideal and eliminate friction and strife, which are both wasteful and irreligious, is infinitely better than a religion which divides mankind into irreconcilable religious groups on the one hand and of scientists on the other.

Science and religion together, then, must build the future. Every stone that is used in the construction of the ideal social temple, that does not accidentally fit into the structure, must be quarried and fashioned by science; it must be laid in the spirit of love and service, that is, in the spirit of true religion. True science and true religion are really one, as means to human perfection. They must be recognized as such before they can be finally and permanently reconciled.

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[6] "Science and Christian Tradition," New York, 1899, p. 255.

A SUMMER ON LOGAN RIVER

By Professor JAMES G. NEEDHAM

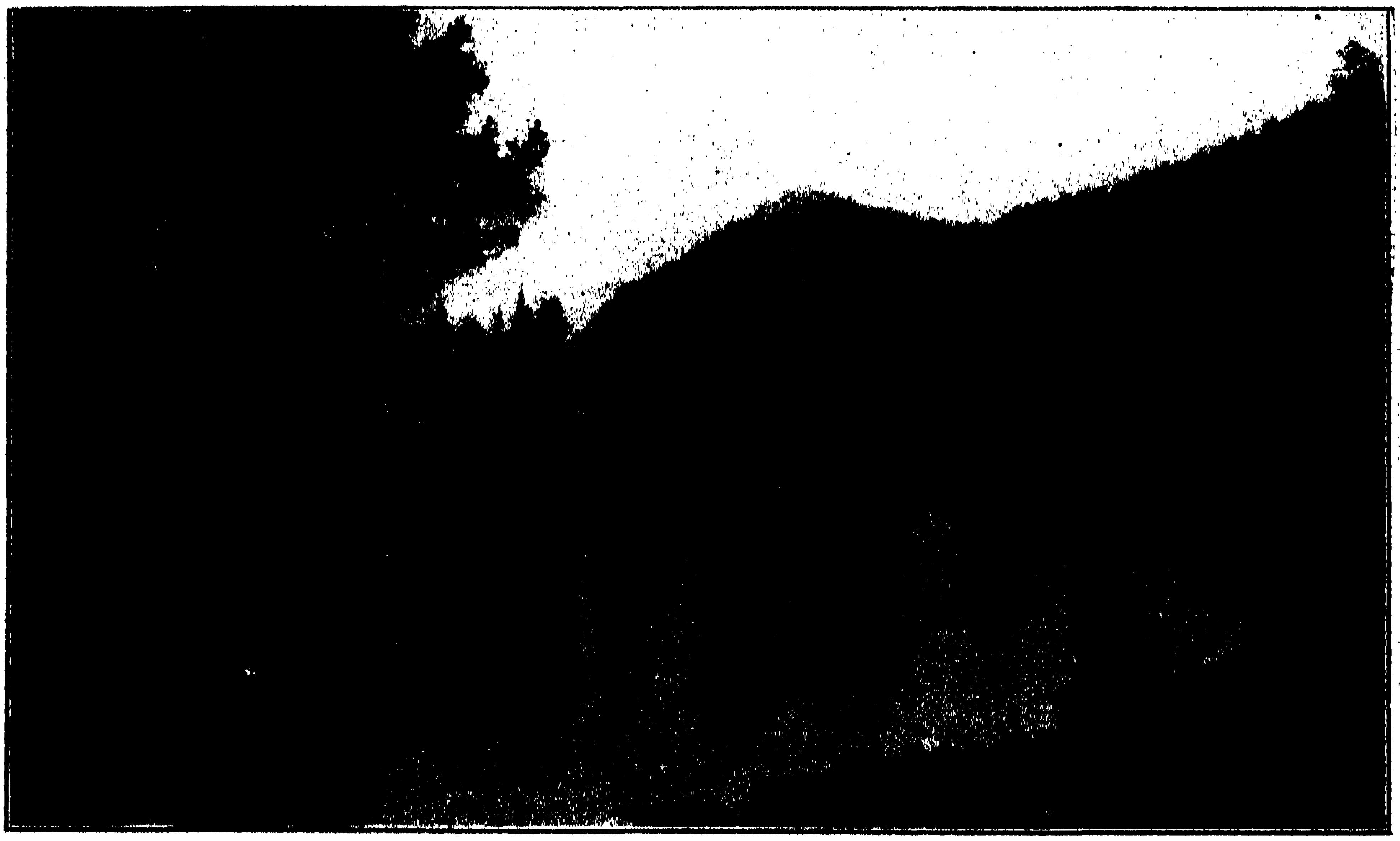
CORNELL UNIVERSITY

On Logan River in Northern Utah in 1926 my ideal of a summer in biological work was realized. I taught in the National Summer School at Logan, but I lived on the river in the heart of Logan Cañon nine miles in the mountains. I took my classes to the river. We collected from its shining ripples, its foaming rapids and its shady pools. We visited the cold springs high up the mountains at its source. We followed it down upon the desert plain. From the crystalline shallows of its upper reaches down to its warm muddy basins below the irrigated fields we followed its changes and gathered samples of its life. The river was our text-book.

Between class sessions I studied the life of the river. I collected from every sort of situation it offered. I reared nearly all its hitherto unidentified insect larvae and returned home heavy laden with the summer's spoils.

There were several conditions that were unusually favorable. It was a season of low water, which made for good collecting. There were no mosquitoes. I lived in Professor A. J. Hansen's cottage at Birch Glen, and it was equipped with everything I needed for my work. It stood near a bridge under which I found a place of safety for my rearing cages. Not a cage was molested all summer long. It was located above all power and irrigation developments where the stream is quite natural. I had for a partner and helper Mr. Reed Christenson, and his automo-

A COLLECTING PARTY IN THE BEAR RIVER RANGE
LEFT TO RIGHT, THE AUTHOR, DR. GEORGE R. HILL, MR. D. F. HEYWOOD, DR. F. P. VANDUZEE, MR. LORING RICHARDS AND DR. I. M. HAWLEY.



WHITE PINE LAKE IN THE BEAR RIVER RANGE
Upper Logan River Valley, Utah. Altitude, approximately 8,500 feet.
Photo by M. B. Linford.

bile in the course of the summer ran some five thousand miles on collecting trips that we took together.

Logan River is a beautiful mountain stream. It rises at some eight thousand feet elevation in the Bear River range of the Wasatch Mountains and emerges on the plain of the Cache Valley at about four thousand five hundred feet. In its upper reaches the bordering slopes are overspread with fields of sage and groves of aspen. These thick clustering groves are very beautiful: the trees seem as gregarious as the sheep that are herded in the intervals between. The edges of the sage clumps are ornamented with scarlet castilleias and with goldenrods; and the frequent moss-grown springs are bordered with yellow monkey-flowers. Their outflowing brooks are choked with water-cress.

Farther down the river winds through a deep cañon, whose rocky walls between the jutting gray ledges are overspread with a low silvery drapery of sage, or with a taller but equally silvery cover of mountain mahogany. Here and there are tuftings of the richer green of cedars on the southern, and of spruces on the northern exposure. Tall summits of bare rocks rise like battlements distantly, often seeming to be carved by wind and weather in architectural columns.

The floor of the cañon at Birch Glen (four thousand nine hundred feet) is covered with trees. Clustering birches and willows border the stream. Interspersed clumps of red-berried elder flowered beautifully in June, and later the wild clematis spread its white blossoms everywhere in charming confusion. The river itself here flows steadily over a bed of stones, with no falls and with hardly any scour-basins or sand bars. At the bridge where our rearing work was done, it is deeper and its surface is wrinkled rather than rippled by the slackened flow; but near at hand are rocks and foaming rapids.

This is a wonderful trout stream. I never saw so many anglers in so small

OVERHANGING ROCK
On the right fork of Logan River above the Boy Scouts' Camp.

a space. There were literally hundreds of fishermen. They were fishing at all times and few there were among them who did not catch trout. There were mountain herring also, *Coregonus williamsoni*, in the stream, though I did not see any of them caught. Kingfishers flew occasionally up and down the river and bobbing water-ouzels stood upon the rocks, courtesying, or made sudden dashes underneath the rapids.

The stream abounds in stoneflies and mayflies, and these feed the trout. From one square yard on the abutments of the bridge at Birch Glen I picked the cast skins of 113 stoneflies; and 82 of these were skins of the big fellow, *Pteronarcys californica,* near two inches long. This great, lumbering, black, archaic insect was flying everywhere on the lower river by the end of June. Females would fly out into the green lane between the trees over the river, slowly flopping their broad wings, Pterodactyl-like in aspect, and without stopping or descending at all, would release a roundish cluster of eggs that would fall like a raindrop into the stream. Thus is the food-supply of the trout renewed.

I reared ten species of mayflies at Birch Glen—some of them very common and very important as forage organisms. One of these (since named by me *Rithrogena fraterna*) was a remarkably pretty nymph, having gill plates of rose-red color arranged as a fringe around its body to form a sucking disc, by means of which it adheres to smooth stones in the swiftest waters.

There was genuine interest on the part of my classes in finding these and other things, and in participating in a pioneer work of exploration. There were temperature preferences observable in the stream. There was an entire change of

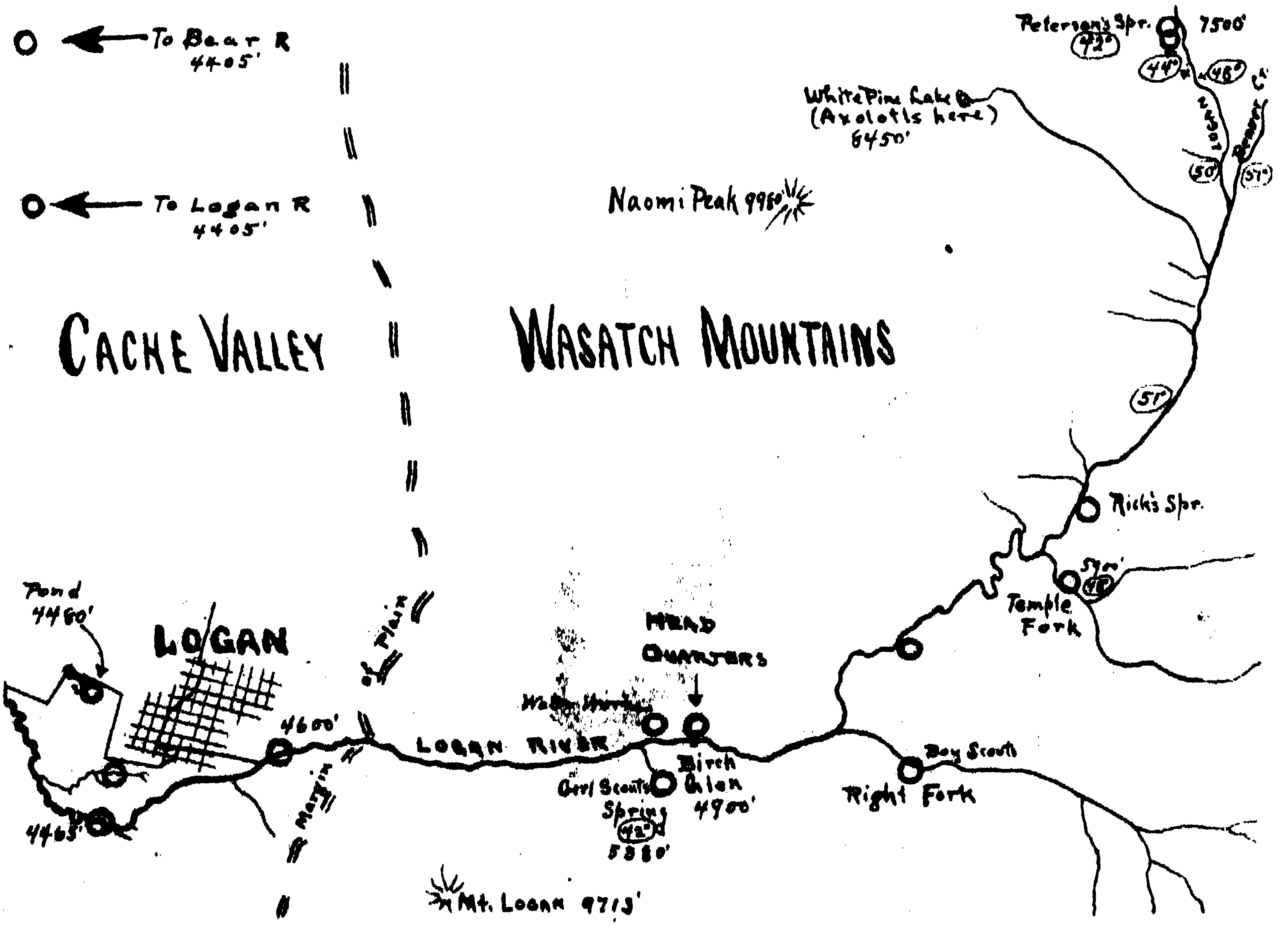
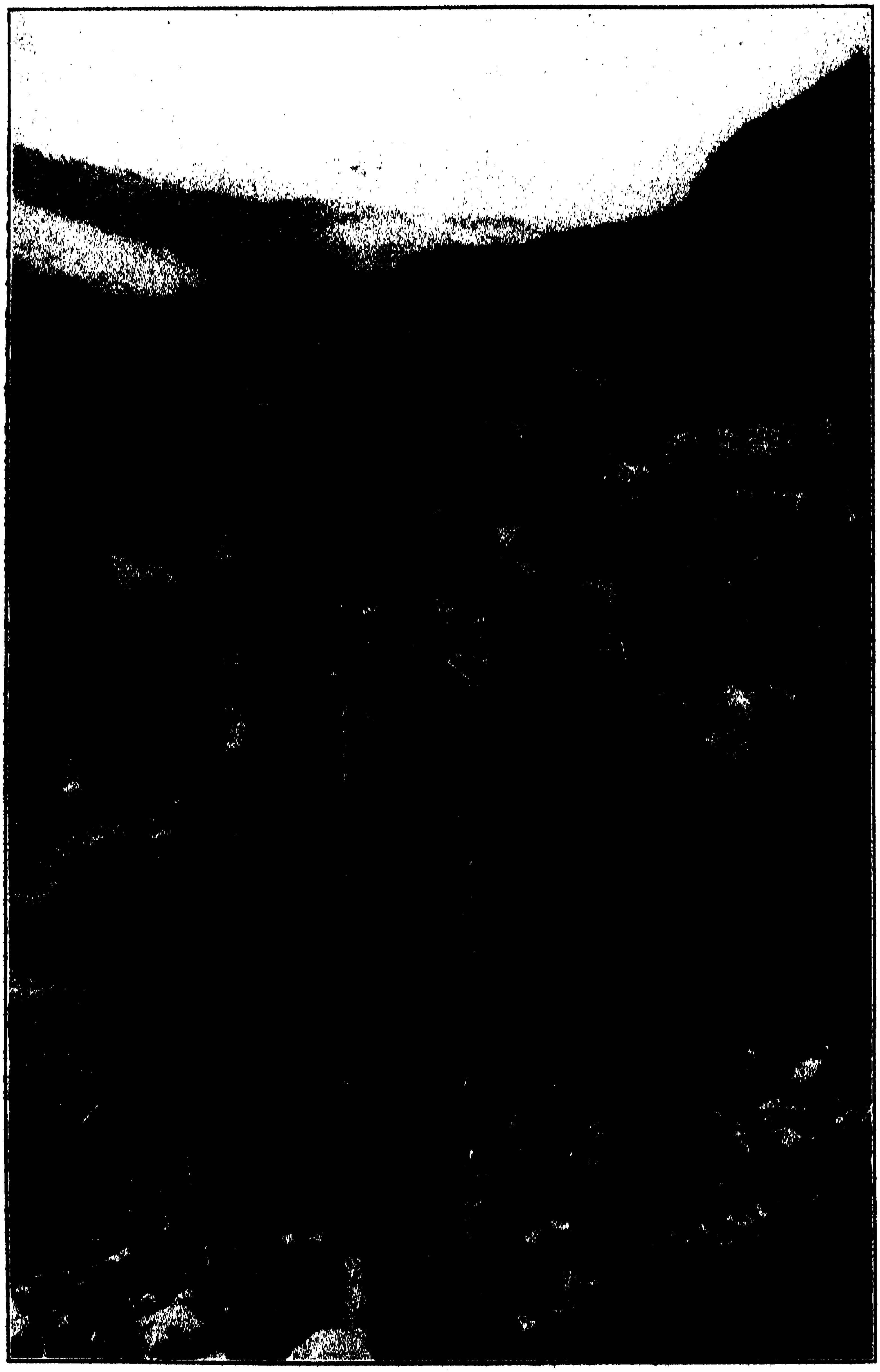


FIG. 1. SKETCH MAP OF LOGAN RIVER

BLACK CIRCLES INDICATE PRINCIPAL COLLECTING PLACES. FIGURES GIVING ALTITUDES ARE ONLY APPROXIMATE. TEMPERATURES OF SOME OF THE COLDER WATERS ARE GIVEN IN DEGREES FAHRENHEIT WITH A LINE DRAWN AROUND THEM.



WHITE PINE LAKE

AND THE SNOW FIELDS BEYOND IT, AS SEEN FROM THE RIDGE ABOVE. *Photo by M. B. Linford.*

fauna with the emergence of the river from the cañon onto the plain. There were examples of altitudinal distribution, as marked as those of the trees upon the slopes. The accompanying sketch map shows where we held class sessions on the river.

We left the river for two afternoons at Dry Lake in the farther (southern) rim of the Cache Valley. One trip was made on June 24th, when the water was low (maximum depth about eighteen inches). The other was made July 22nd, when the water was almost gone (maximum depth about six inches).

This lake occupies a little basin between low mountain tops at an elevation of five thousand six hundred and sixty feet. It fills with the melting of the winter snows and is then a mile or more across in any direction. Its waters disappear entirely in the late summer, and a crop of wild hay is cut from the peripheral portion of its bed by the farmers who own the land.

There were a few acres of open water at the time of our first visit in June. Some clumps of lake bulrush emerged here and there and waterfowl were abundant in their shelter. Surrounding

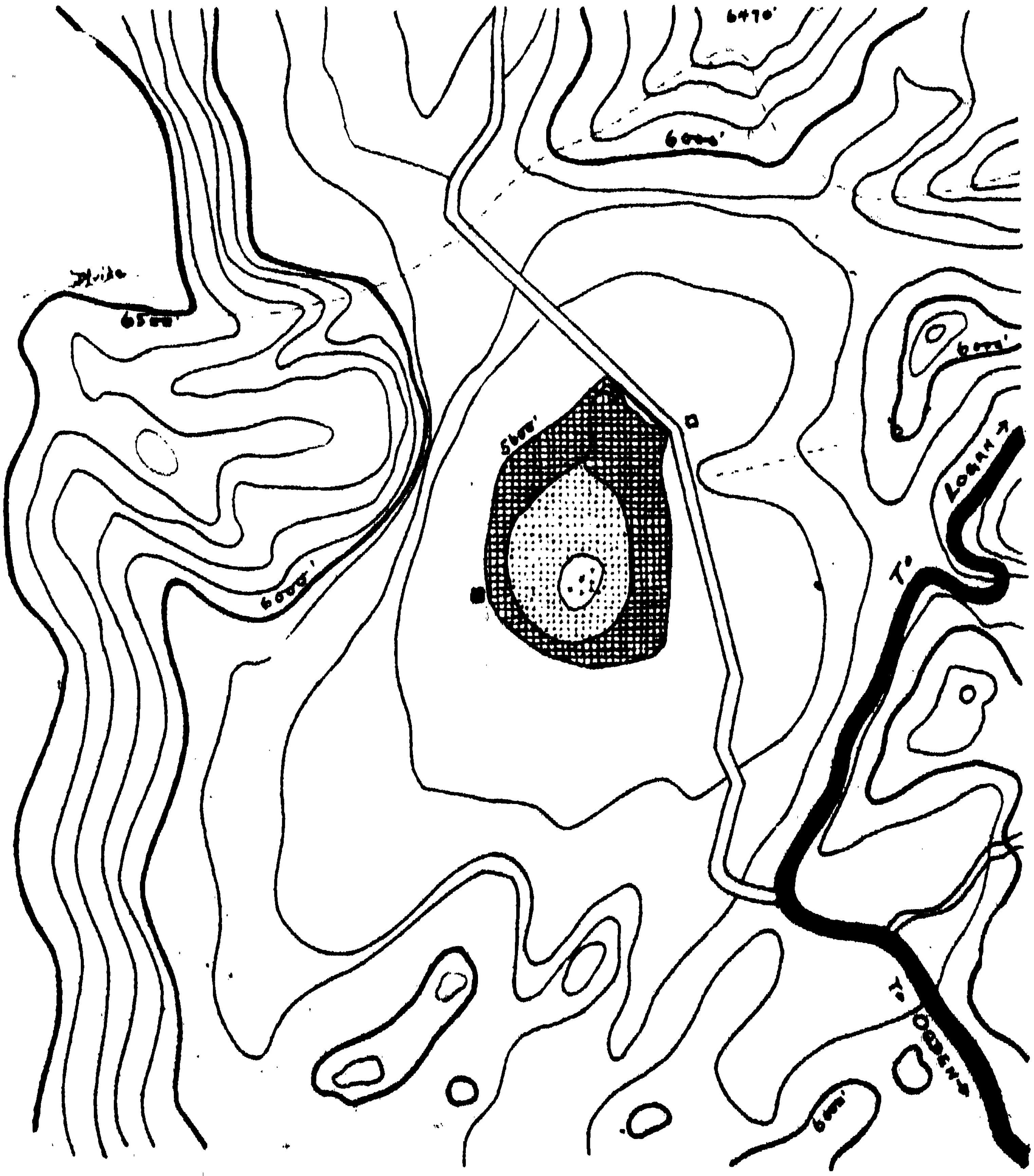
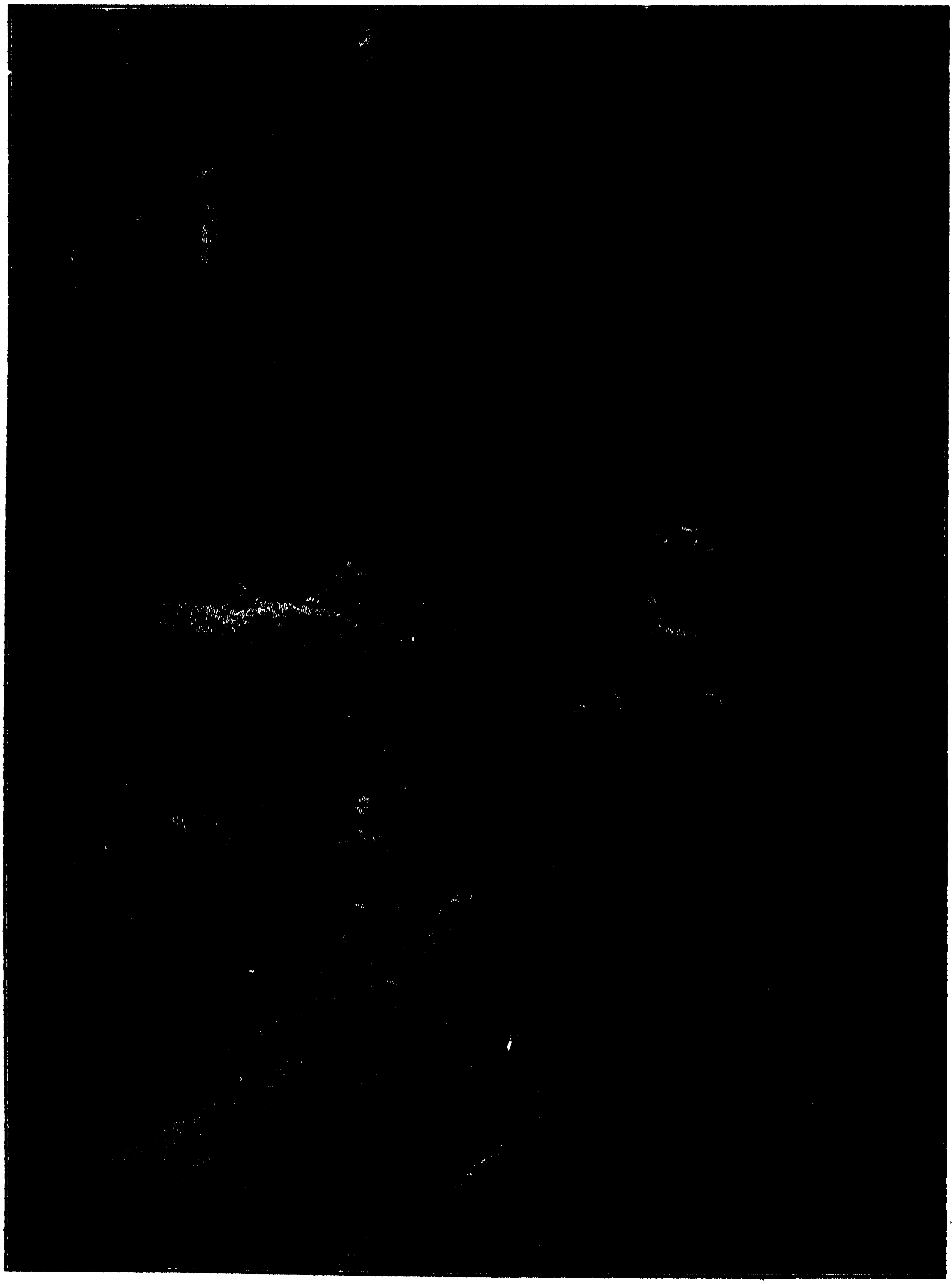


FIG. 2. DRY LAKE, UTAH, THE HOME OF THE PADDLE-TAIL, *LEPIDURUS COUESII*

THE ABOVE IS A COPY OF WHAT MY FRIEND, PROFESSOR ALFRED C. BURRILL (WHO WAS WITH ME AT DRY LAKE) CALLED A "PANTOGRAPH DISTORTION" AND ENLARGEMENT OF A PORTION OF THE LOGAN QUADRANGLE, U. S. GEOL. SURVEY, WITH THE OGDEN-TO-LOGAN STATE HIGHWAY ADDED; ALSO WITH ZONATION ON LAKE BED AS FOUND BY US ON JUNE 24TH. THE CROSSLINED AREA WAS DRY. THE STIPPLED AREA WAS SPIKERUSH IN VERY SHALLOW WATER (DRY ON OUR LATER VISIT). THE INNERMOST AREA WAS OPEN WATER WITH CLUMPS OF LAKE BULRUSH ("TULES").



A FALLEN GIANT

OF THE BULL CREEK REDWOOD GROVE. JOHN T. NEEDHAM, CUSTODIAN OF THE MUIR WOODS, NATIONAL MONUMENT, STANDING BESIDE IT. CALIFORNIA, 1923. *Photo by J. G. Needham.*

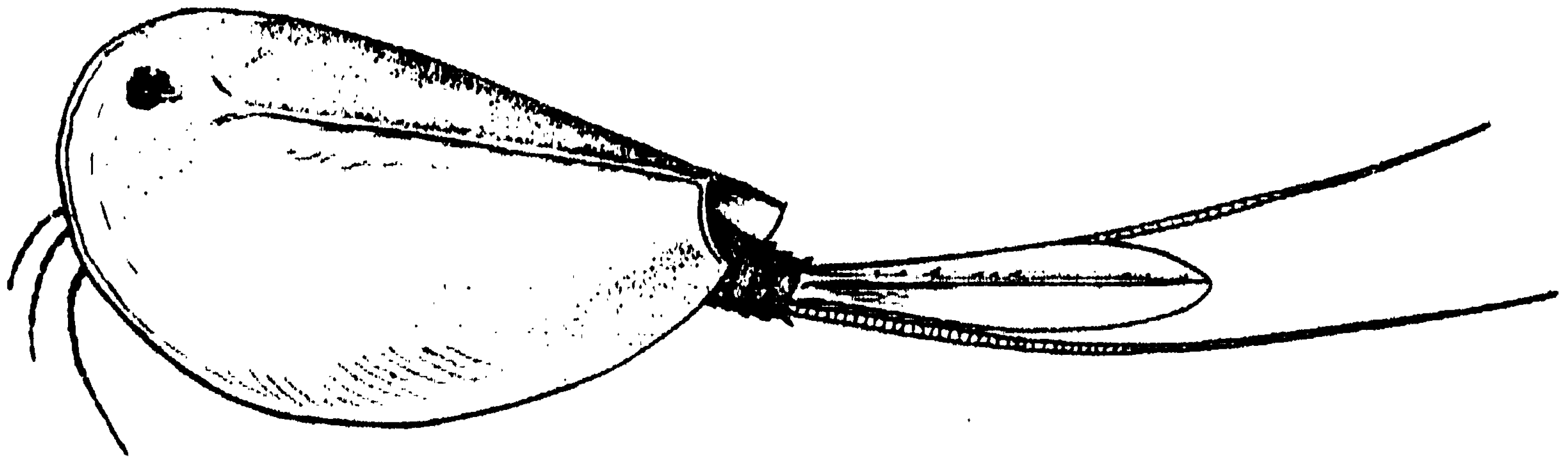


FIG. 3. THE PADDLE-TAIL, *Lepidurus couesii* × 2.

the open water was a very broad belt of bright green meadow, composed of spike rush (Eleocharis), in very shallow water. Numberless damselflies (*Lestes uncatus*) were emerging, and their cast nymphal skins were hanging on the rushes everywhere. The unique phyllopod crustacean, *Lepidurus couesii,* was quite common, though already disappearing. When we returned in July this was gone and the water was gone from the spikerush zone, and the bladderwort, *Utricularia vulgaris,* had shot up tall peduncles of bright yellow flowers. What a place to study seasonal succession if only one were there!

But we only visited Dry Lake. We lived on the river. And it was another source of satisfaction to me to see the members of my class quickly discovering how easy it is to pick up some real knowledge of the life of a stream. Trout fishing is a principal sport of residents in Cache Valley in the summer time; and the fishing is not so good as once it was, when the dangling lines were fewer. What can be done about it? is the common question; and while there are many answers there are none that are solidly based on facts. There is plenty of guessing. My classes went fact-finding. It was quickly apparent that food was not the limiting factor at Birch Glen, as had been supposed. The river teemed with the best of forage organisms, nymphs of mayflies and of herbivorous stoneflies; and the trout were fat. Other parts of the stream were full of competing carnivores and the trout were lean and ill-conditioned.

So the work of the summer included this contact with the practical interests of the people. For purposes of instruction it used only local materials; none better could have been found. It yielded scientific results of some value. It all met with the friendliest cooperation; and it was done amid scenes of novelty and beauty. Would that there were more opportunities in America for combining the teaching of classes (for which alone we get paid) with research in the field.

TRANSATLANTIC TELEPHONY[1]

By Dr. FRANK B. JEWETT

VICE-PRESIDENT OF THE AMERICAN TELEPHONE AND TELEGRAPH COMPANY

As long distance radio telephony sprang much more directly than is commonly realized from experiments and actual experience with long distance wire telephony, I will relate a little history very briefly. About the year 1890, the type of pole line structure that New York City required for its long distance telephone service was that of Figure 1. The poles of this line were some ninety feet high and at some points carried thirty crossarms and, therefore, three hundred wires. While there is something about these poles that seems to remind one faintly of the sail plan of a Chinese junk, they were not deemed sufficiently artistic to warrant their being continued in use any longer than was absolutely necessary. They had many disadvantages from the standpoint of the telephone engineer; nor was their presence particularly appreciated by the city fathers of Manhattan. One of the troubles to which this type of line is heir is well illustrated in Figure 2, which shows the destruction that sleet and wind can work in the course of a few minutes.

Intensive research was, therefore, undertaken to find some more desirable telephone line structure than that afforded by these enormous poles. Passing over many intermediate types of long distance line which have been employed at various times and places, let us consider one of the most approved forms yet devised. Its outward appearance is shown in Figure 3. Within a thin lead sheath, about two and a half inches in diameter, many wires are closely packed together, each being insulated by a very thin covering of paper. The particular cable shown here in section contains about 550 wires and, therefore, nearly twice as many as the tall poles of Figure 1. This cable can, of course, be mounted on short rugged poles so as to make it immune to damage by storm, or where desired, it can be placed underground. Bearing in mind that this single cable contains wires enough to form hundreds of individual telephone circuits, you will realize at once that as a structure it represents a great advance. But this is only half the picture, for its electrical advantages are as pronounced as its structural advantages.

Indispensable in connection with the operation of such a cable, as well as of all long distance lines, is the telephone current amplifier, generally known as the telephone repeater. It was as long ago as 1905 that an early model of a repeater was inserted in the line then running between New York and Chicago. The action of this repeater was equivalent to shortening that 1,000 mile line by 300 miles. It marked the beginning of long distance telephony, and with this success behind, we knew it to be possible to telephone over great distances both by wire and by radio. In both these undertakings, the fundamental requirement was an amplifier which would raise the energy of the telephone currents without adversely affecting the intelligibility of the message.

We naturally turned our attention first to the development of long distance telephony over wires, and in January, 1915, the first transcontinental circuit connecting New York and San Francisco

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[1] Based on a talk given before the National Academy of Sciences, Washington, D. C., April 25, 1927.

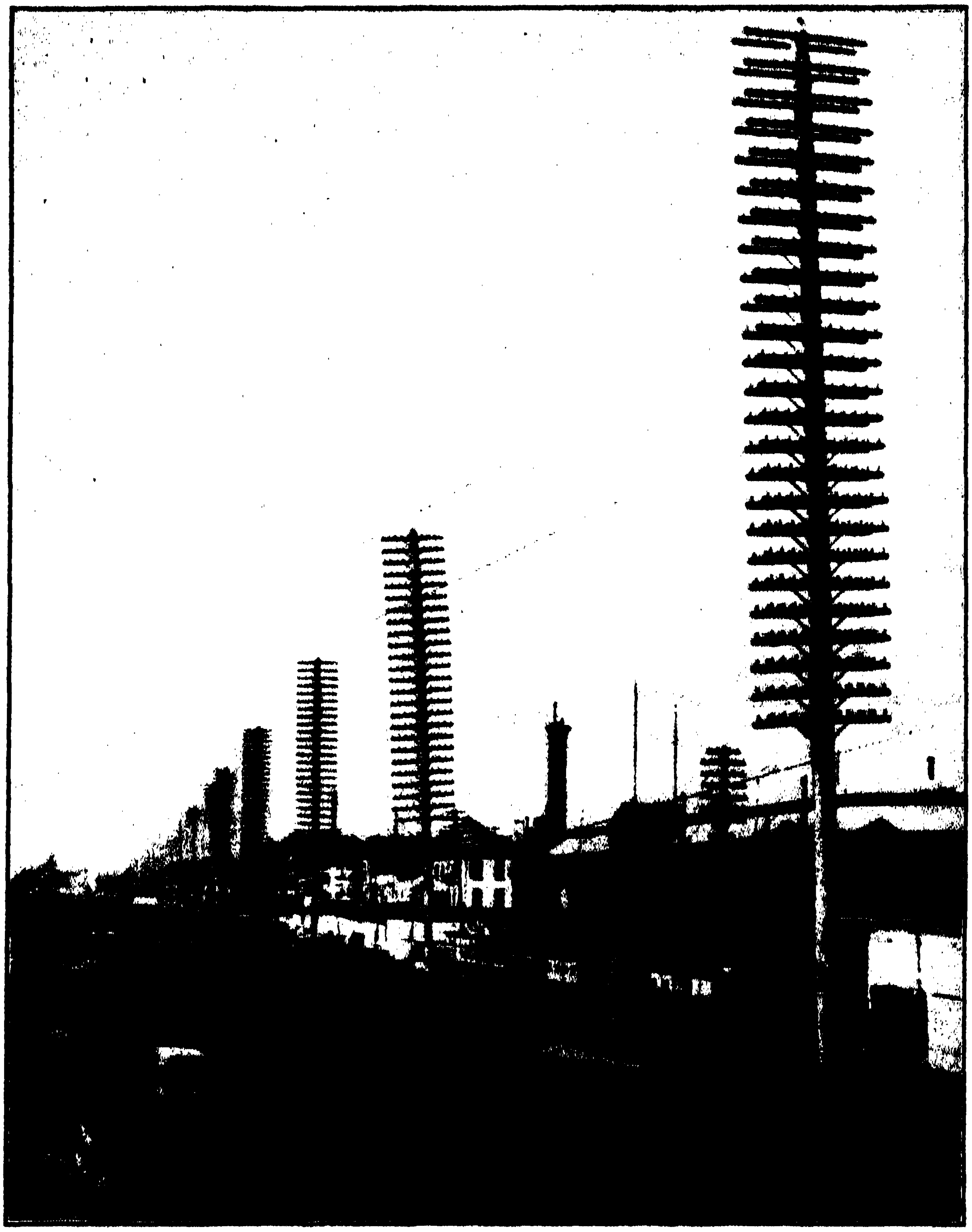

FIG. 1. WEST STREET POLE LINE, NEW YORK CITY, ERECTED IN 1887
90-FOOT POLES, 25 CROSS ARMS, 250 WIRES. AT SOME POINTS IT CARRIED 30 CROSS ARMS AND 300 WIRES. THE PICTURE WAS TAKEN AT THE FOOT OF CORTLANDT STREET.

was opened for service. By good fortune, however, the vacuum tubes used in the transcontinental repeaters proved applicable in several important ways to radio telephony. This is well attested by the fact that in the same year we were able to announce the successful transmission of the voice by *radio* both across the American continent and across the Atlantic Ocean to Europe.

Turning our thoughts back twelve years, we recall that none of the now familiar aspects of radio telephony had put in an appearance. Radio telephony was first used as an instrument of military character by the various armies engaged in the World War about 1917, and broadcasting was probably born about 1920. However, in our search for new instrumentalities of communication, the engineers of the Bell System had arrived in 1915 at the stage which made it possible for them to transmit the voice by radio telephony over a distance as great as 5,000 miles. By means of transmitting apparatus located at Arlington,

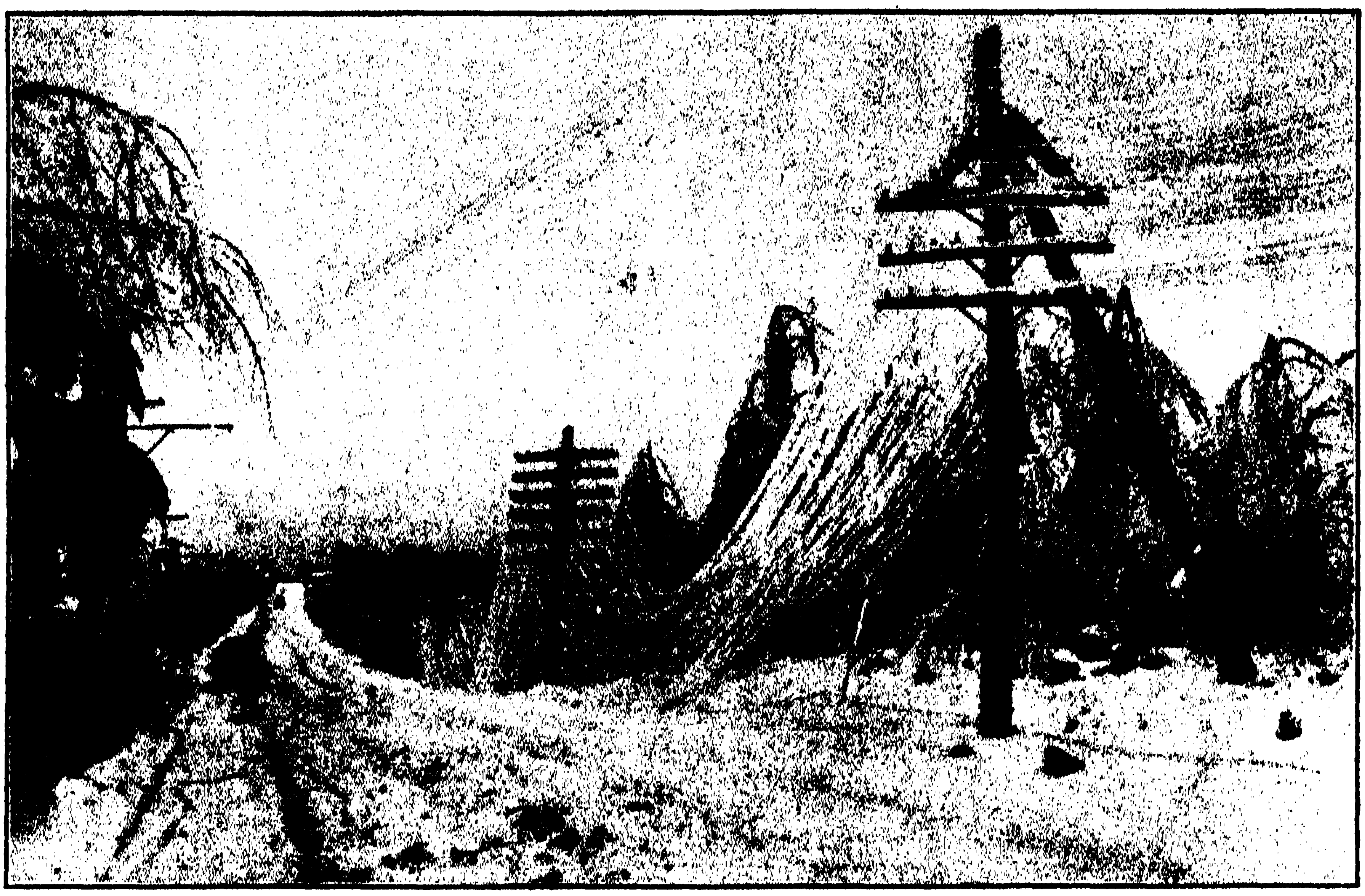

FIG. 2. OPEN WIRE TOLL LINE AFTER SLEET STORM

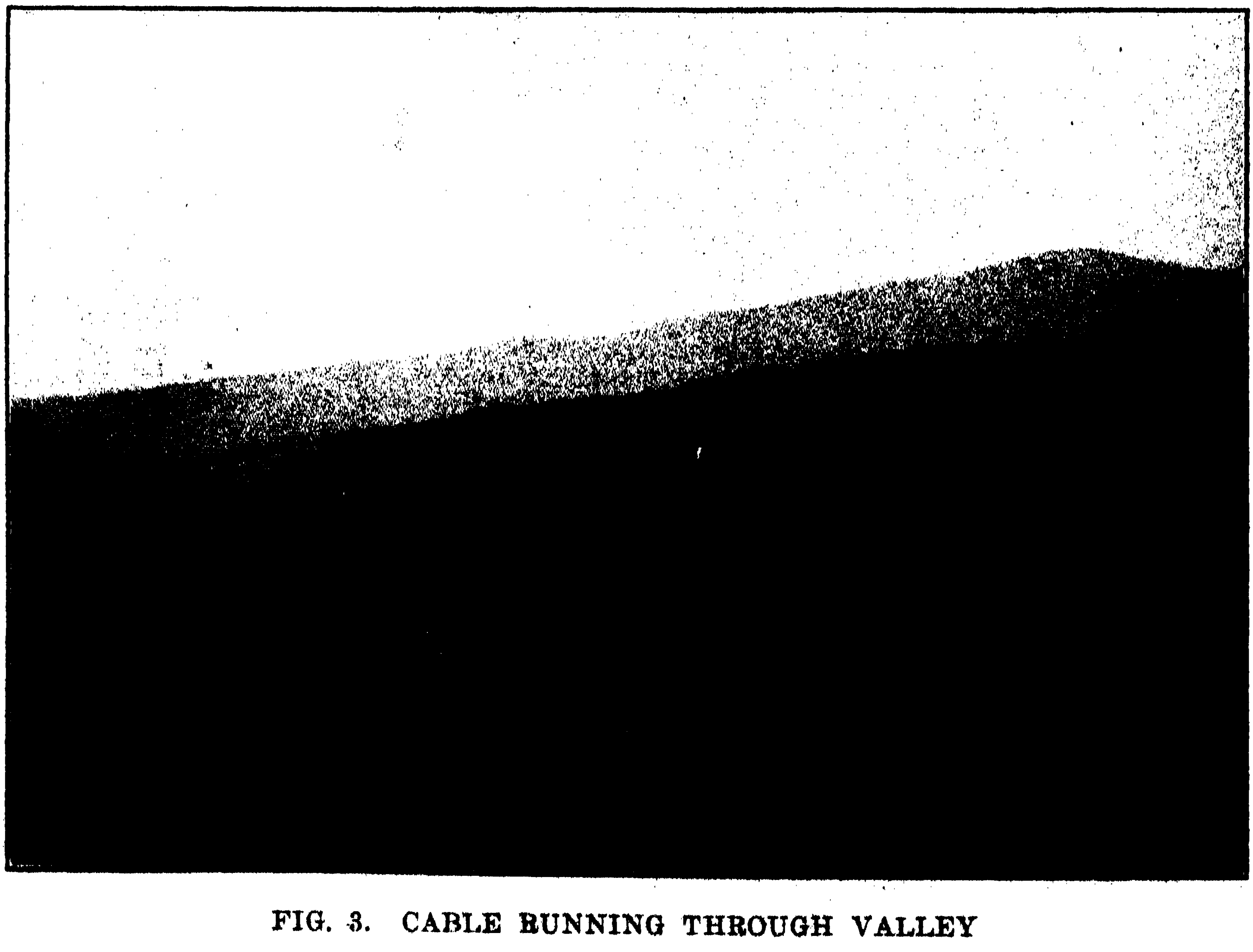

FIG. 3. CABLE RUNNING THROUGH VALLEY

Virginia, we succeeded in sending intelligible speech across the continent to San Francisco and also as far westward as Honolulu. A few weeks later, two of our engineers who had been sent to France, succeeded in receiving speech from Arlington, making use of a receiving antenna located upon the Eiffel Tower in Paris.

While the demonstrations of 1915 were purely experimental, they yielded important results. On the one hand, they proved that transatlantic telephony was in the realm of the possible, and on the other, it gave our engineers a much clearer insight into the difficulties which they would encounter were they to attempt to offer regular telephone service to Europe. In fact, these difficulties stood out so prominently as to leave no doubt that before commercial transatlantic service could be offered, a very extensive program of development and study would have to be completed. It is in this connection that the problems of the applied scientist arise. It was apparent that such a program would not be a matter of months but years, and could not be launched at all while the World War was in progress. Some three years later, however, it was begun and has continued down to the present without interruption.

Even now that regular service to England has been inaugurated, our studies are continuing. This is but one detail of a continuous program of study and improvement. Thus, we have been offering wire telephone service for fifty years, but we are to-day studying its instrumentalities more intensively than ever. I think it can be safely predicted that the more firmly established transoceanic telephony becomes, the more interested we will be in seeking out improvements of the apparatus that makes it possible.

I propose to recount briefly what we have to show as the results of a nine-year study of transatlantic telephony.

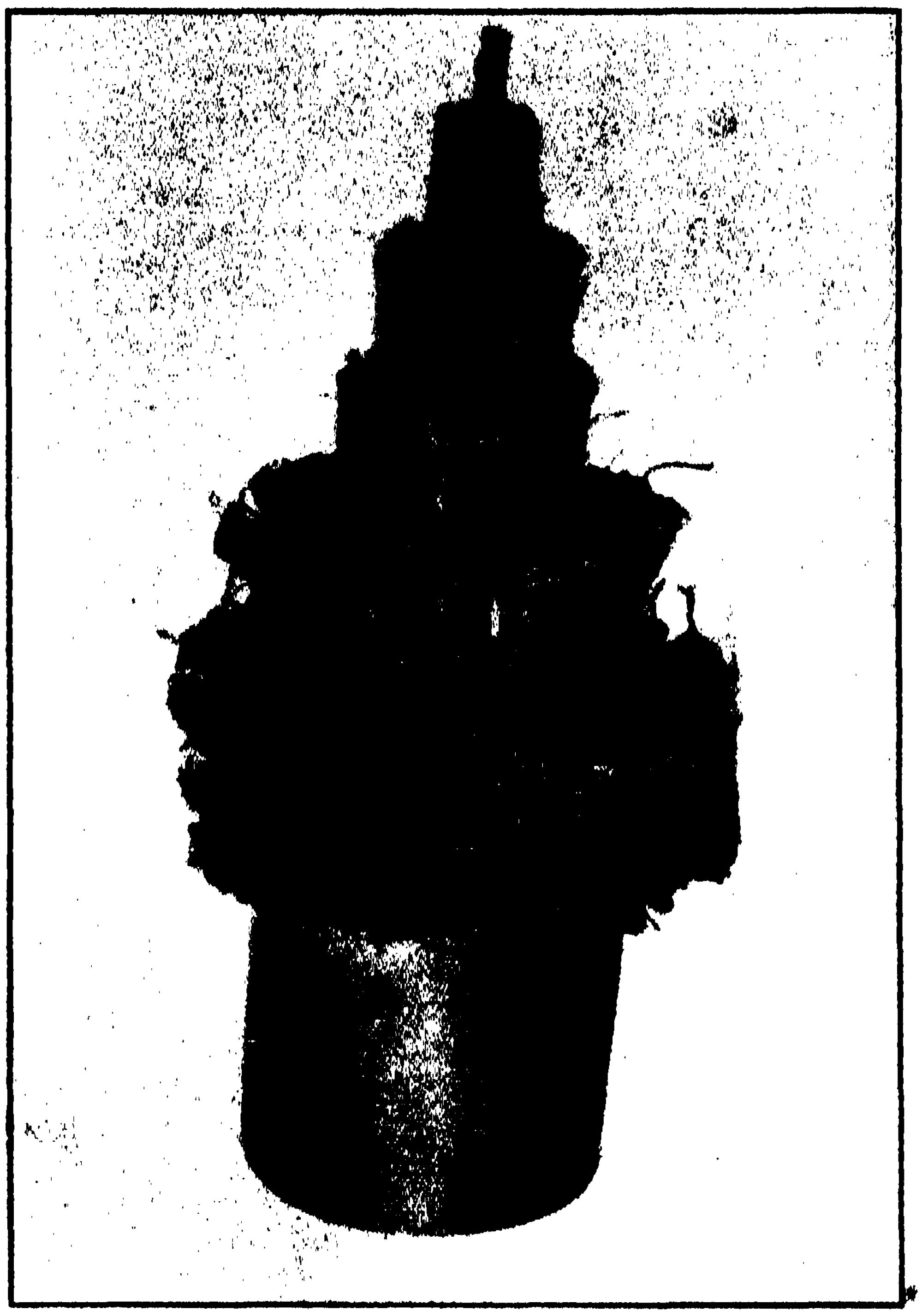

FIG. 3A.—PIECE OF CABLE WITH SHEATH PARTLY REMOVED
TO SHOW THE ARRANGEMENT OF THE WIRES

To-day, nearly everyone is familiar with the more superficial phenomena of radio, particularly radio broadcasting. But probably to most people, the term radio largely symbolizes the particular receiving set that they happen to make use of for picking up programs. To them, the phenomena of transmission and what goes on at a transmitting station are largely someone else's concern. To the telephone engineer, however, the term radio denotes a complete system comprising a sending station, the surrounding medium of propagation, a receiving station, and usually wire lines connected to both the sending and receiving stations. Then, of course, if the system is to be employed for two-way telephony (which alone would be capable of handling a conversation between two people) it must be extended to include two receiving stations and two sending stations

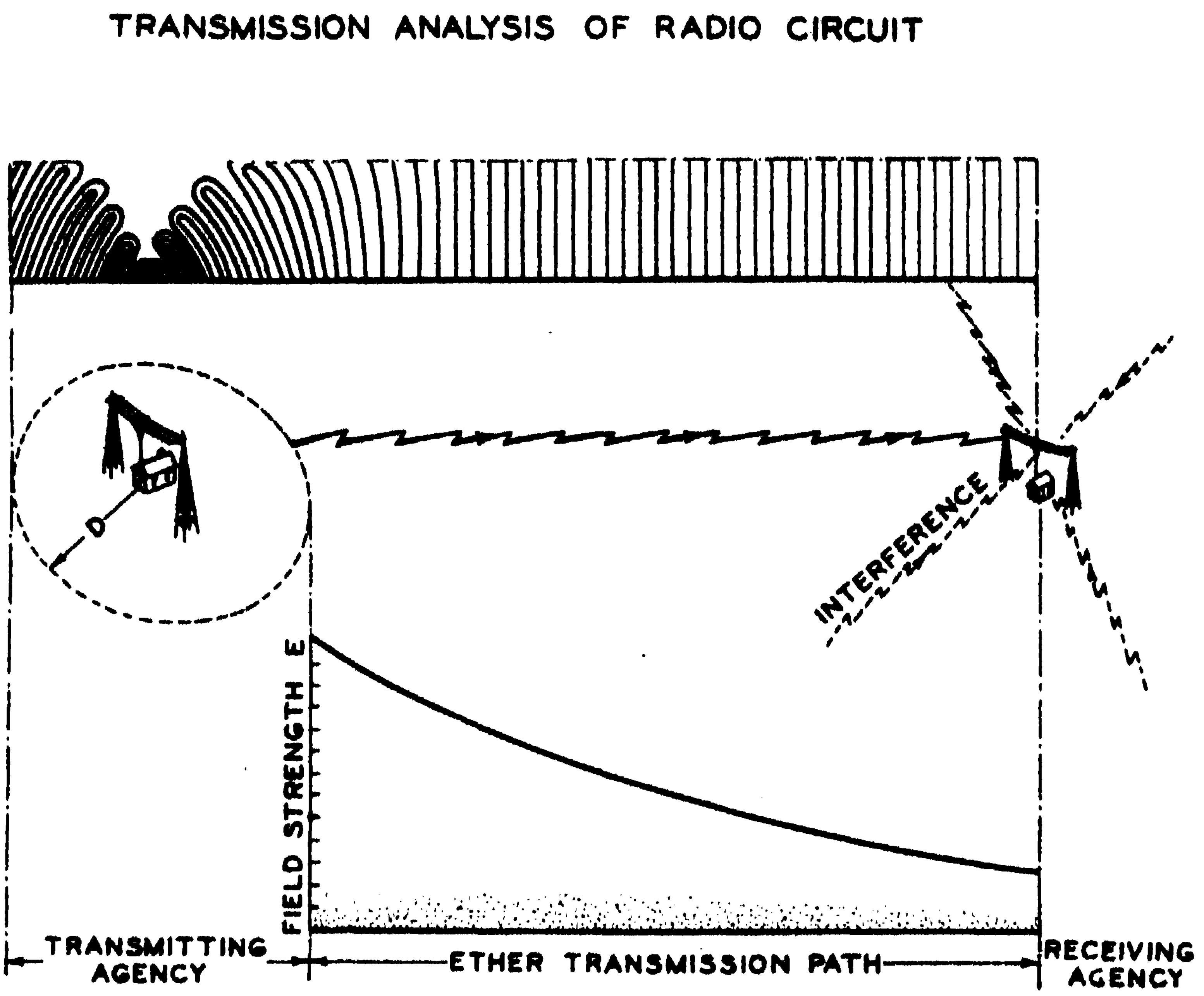

FIG. 4. DIAGRAM OF RADIO WAVES

SPREADING OUTWARD FROM A TRANSMITTING STATION; A SINGLE RECEIVING STATION IS SHOWN.

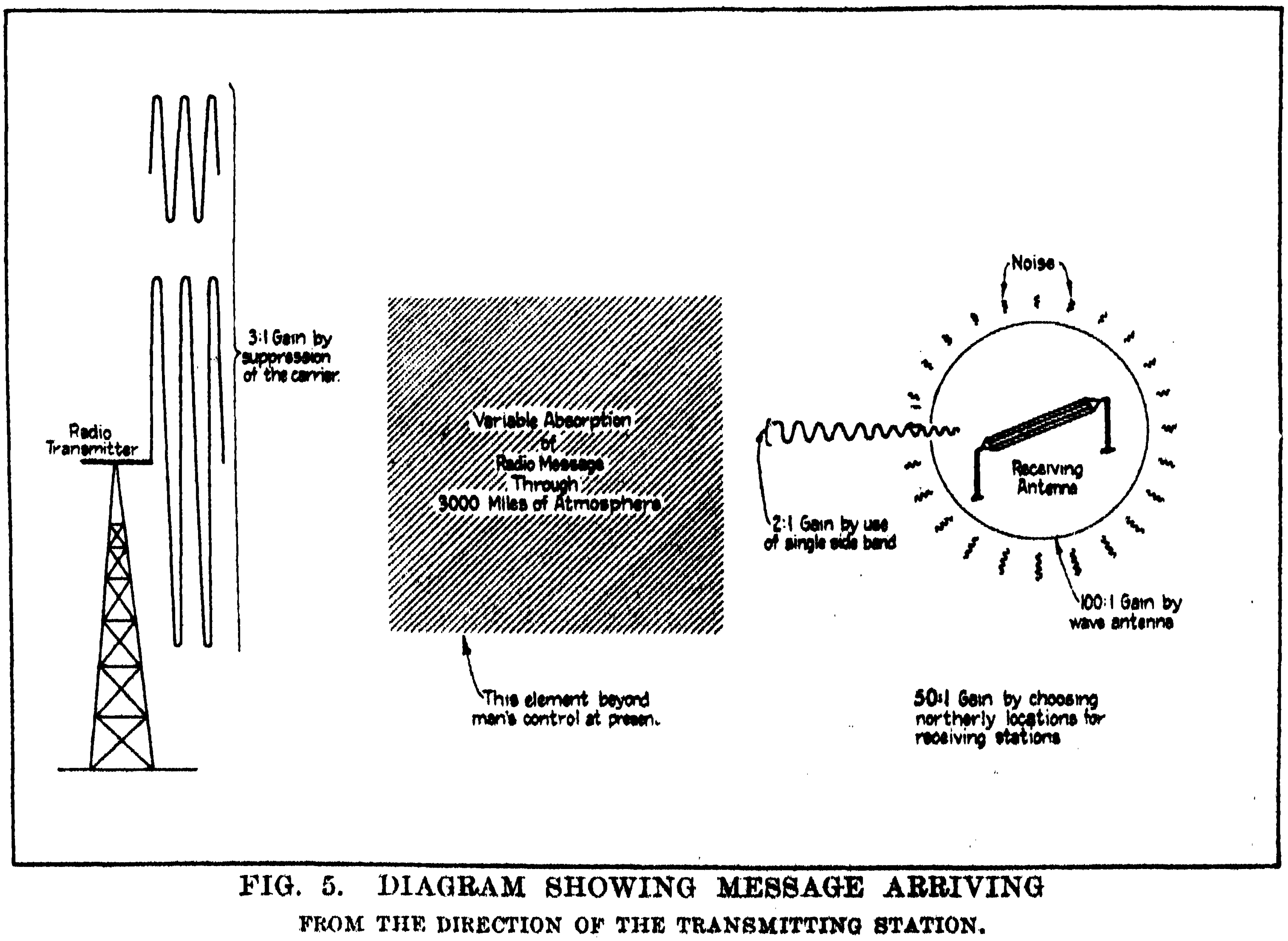
3:1 Gain by suppression of the carrier
Radio Transmitter
Variable Absorption of Radio Message Through 3000 Miles of Atmosphere
This element beyond man's control at present.
Noise
2:1 Gain by use of single side band
Receiving Antenna
100:1 Gain by wave antenna
50:1 Gain by choosing northerly locations for receiving stations

FIG. 5. DIAGRAM SHOWING MESSAGE ARRIVING

FROM THE DIRECTION OF THE TRANSMITTING STATION.

with means for properly connecting them together by wire lines.

In dealing with such a radio telephone *system* one is faced with the necessity, or perhaps it would be better to say offered the opportunity, of coordinating the various component parts to secure the best results. To show the improvements and the progress that become possible when the engineering of a complete system is undertaken, I will contrast, from time to time, throughout my talk, radio telephony as it exists to-day in the form of broadcasting with the radio telephone system which we are now employing for handling calls to Great Britain.

Let us begin by considering the simplest possible type of radio telephone system. Figure 4 represents a single transmitting station and a single receiving station, and at the upper margin the radio waves are illustrated as spreading outward from the former. As they travel outward they, of course, become fainter and fainter in some such manner as illustrated by the drooping curve below. Now it is unfortunately a fact that our receiving antenna is subject to undesirable radio influences—to interference—as well as to the single message which we want to pick up. Static is one well-known form of interference and the signals emanating from other stations, particularly telegraph stations, is another familiar form.

If it were not for interference in radio, the communication engineer's problem would be ever so much simpler than it is. Then it would merely be a question of transmitting the message through space and picking it up at the receiving point, regardless of how faint it had become; and should it be too faint to be readily heard by the ear, it would, of course, be a simple matter to amplify it enough to make it audible. In the presence of interference, however, it is necessary that the message, when picked up by the receiving antenna, be sufficiently intense to *override* that interference. Putting this matter more directly, one might say that due to the interference, it might be necessary to deliver the message to the receiving station with perhaps a million times as much power as would otherwise be necessary. In a very real sense then, the problem of the radio engineer becomes one of combating ether interference.

In the first place, by treating the transatlantic system as a whole, we have been able to effect a substantial gain in efficiency at the radio transmitter. By using the "suppressed carrier" system of transmission, the high frequency power generated by the transmitter is utilized *three times* as effectively as in broadcasting. Another development, known as single side-band transmission, has also augmented the efficiency of the transmitter and a little later I shall mention the gain resulting from this.

After the message leaves the transmitting antenna, it must pass through some 3,000 miles of the earth's atmosphere. Here it encounters a degree of absorption which varies from hour to hour, from day to day and from season to season. Over this transmitting medium man has, as yet, little if any control. Conditions existing at certain times, notably at night, are more favorable than those found at other times, and knowledge of such more or less systematic variations would enable us, other factors permitting, to carry on our exchange of messages at the most favorable times. But this is far from constituting control of the atmospheric influences and it will only be after more extended investigation and study, if at all, that we can devise a radio system in which transmission will be appreciably independent of such factors. It may be interesting to point out that in the present state of the art, the influence of the atmosphere is so great that while at times a very small amount of power will suffice to get a message through, only a few hours later 10,000 times as much

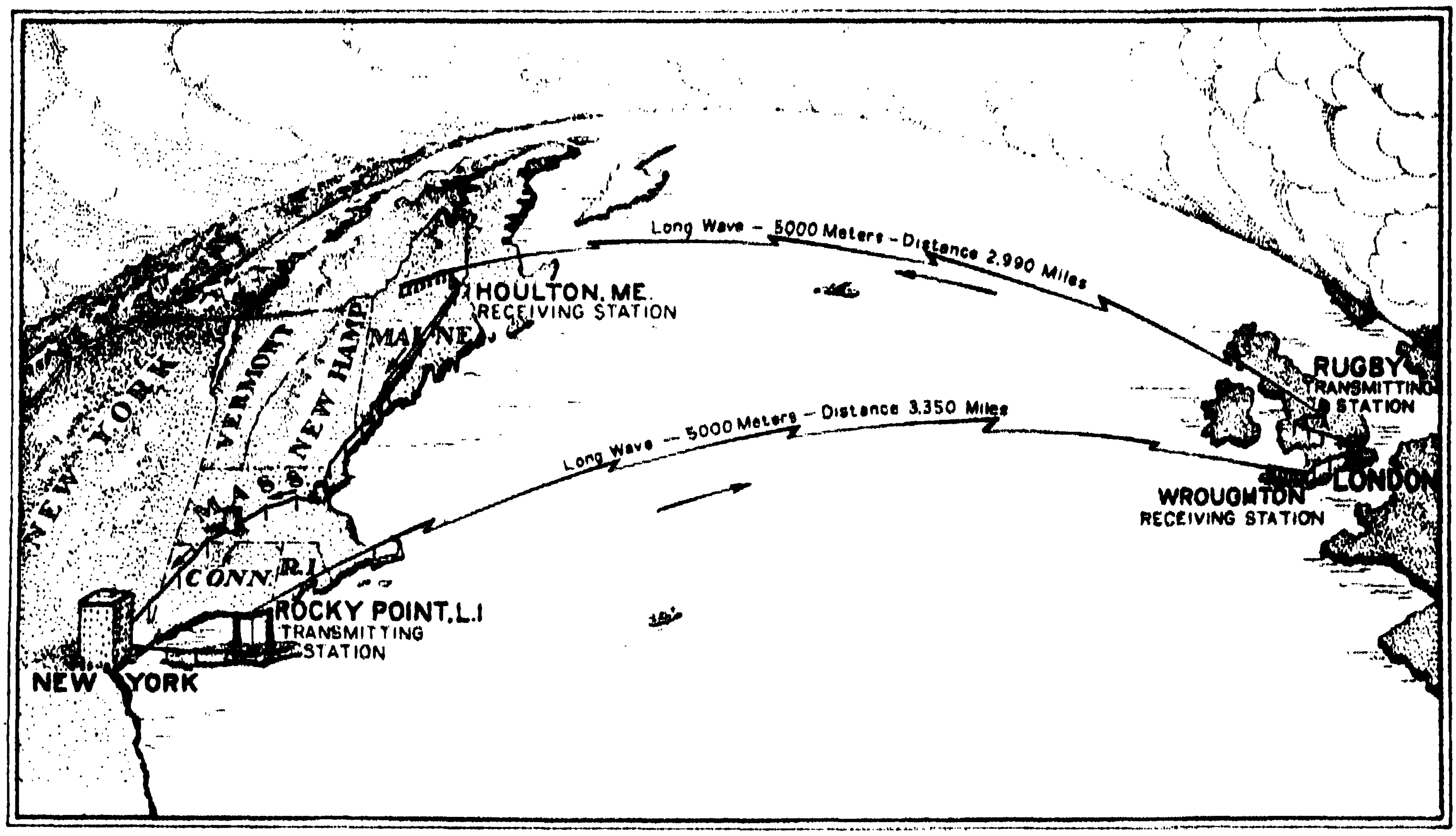

FIG. 6. MAP OF THE WIRE AND RADIO LAY-OUT FOR TRANSATLANTIC MESSAGES.

power may be required. As a matter of fact, the transmitters are operated at constant full power. Under good conditions, this allows a margin of safety; under very poor conditions it may be insufficient.

When we reach the receiving station we are at the scene of many notable achievements. Figure 5 has been so drawn as to show the desired message arriving from the direction of the transmitting station, and it also shows the receiving antenna under the influence of interference or noise coming from all directions, of course including that from which the message comes. It is apparent from the drawing that if, *in effect*, we could surround the receiving antenna by some sort of a shield which is open only in the direction from which the desired messages come, we could eliminate a large part of the interference. This result has been accomplished, not by enclosing the receiving antenna in a screen, but by so designing the antenna itself that it is highly directional in its response, being virtually insensitive to signals coming from directions other than that followed by the message. So effective is our present antenna that as a device for discriminating in favor of the message and against the interference, it represents a one hundredfold improvement over the loop antenna now so commonly used in broadcast reception. Hence it is equivalent, from the standpoint of the transatlantic radio system, to a one hundredfold increase in the power of the transmitting station.

I mentioned previously that we are employing the single side-band type of transmission. This enables us, in effect, to narrow down by one half the opening through which the message is admitted to the receiving set. This decrease of the opening by one half works no hardship upon the message but does, of course, reduce by about one half the amount of interfering noise which would otherwise be picked up.

As another step, we found, after a long series of observations conducted along our Atlantic seaboard, that by locating the receiving station well north, a decided improvement so far as freedom

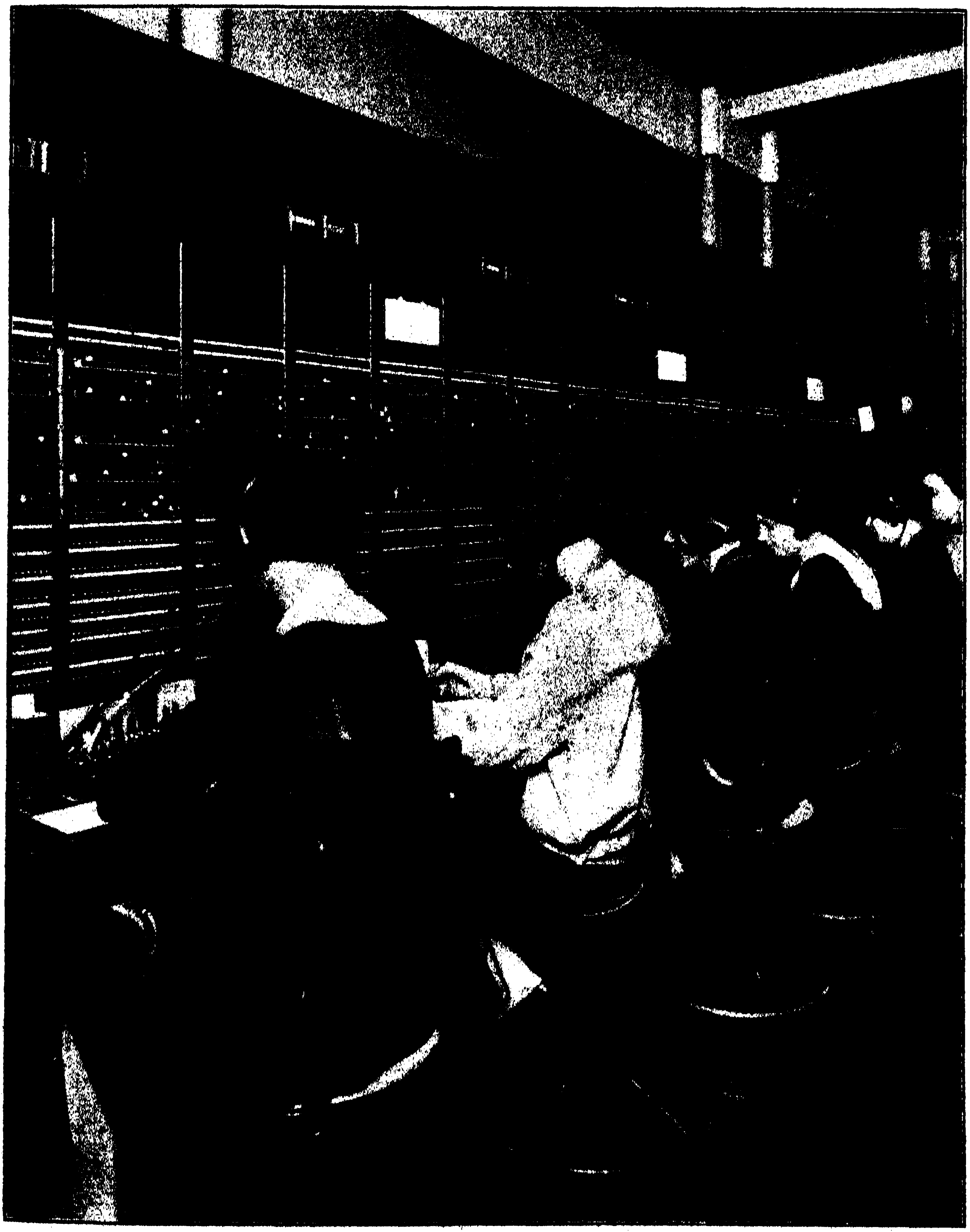

FIG. 7. THE OPERATORS AT 24 WALKER STREET, NEW YORK CITY WHO HANDLE THE TRANSATLANTIC TRUNK. POSITION 104 IS THE TRANSATLANTIC BRANCH AND 103 AND 105 ARE THE OPERATORS WHO HANDLE THE LINES TO THE LOCAL SUBSCRIBERS.

from interference is concerned, could be obtained. Our western receiving station is now located at Houlton, Me., well up in the northern corner of the state, and observations show that this secures for us something like a fiftyfold improvement over that to be had around New York or Boston.

Totaling up the effect of the developments which I have just described, we arrive at a surprising figure—by suppression of carrier a threefold gain; by single side-band transmission two more or six; by a northern site for the receiving station, fifty more or three hundred; and finally by the directional antenna one hundred more or a total of thirty thousand. That is, the transatlantic telephone system as it stands to-day is some 30,000 times as efficient as the best that there is available in the field of radio broadcasting. This does not mean that broadcasting systems are unsuited to the particular purpose for which they are used, but it indicates that something tremendously more efficient had to be developed for successful transatlantic telephony. This is a truly astonishing figure and well worth the years of study it has involved. But our studies are not over, for we believe that we have by no means reached the limit of possible improvements.

Figure 6 shows in diagrammatic form the wire-radio layout made available to a subscriber on one side of the Atlantic when he converses with a subscriber on the other side. The western telephone, connected by a wire line to New York City, may be any telephone in the United States. This wire line terminates in the long-distance headquarters in New York, from whence another line runs out Long Island to Rocky Point where the radio transmitter is located. Over the wire line the message travels as any ordinary telephone message. Upon reaching Rocky Point it must be prepared for the transatlantic jump and for this it is, among other things, amplified greatly—upwards of two billion times.

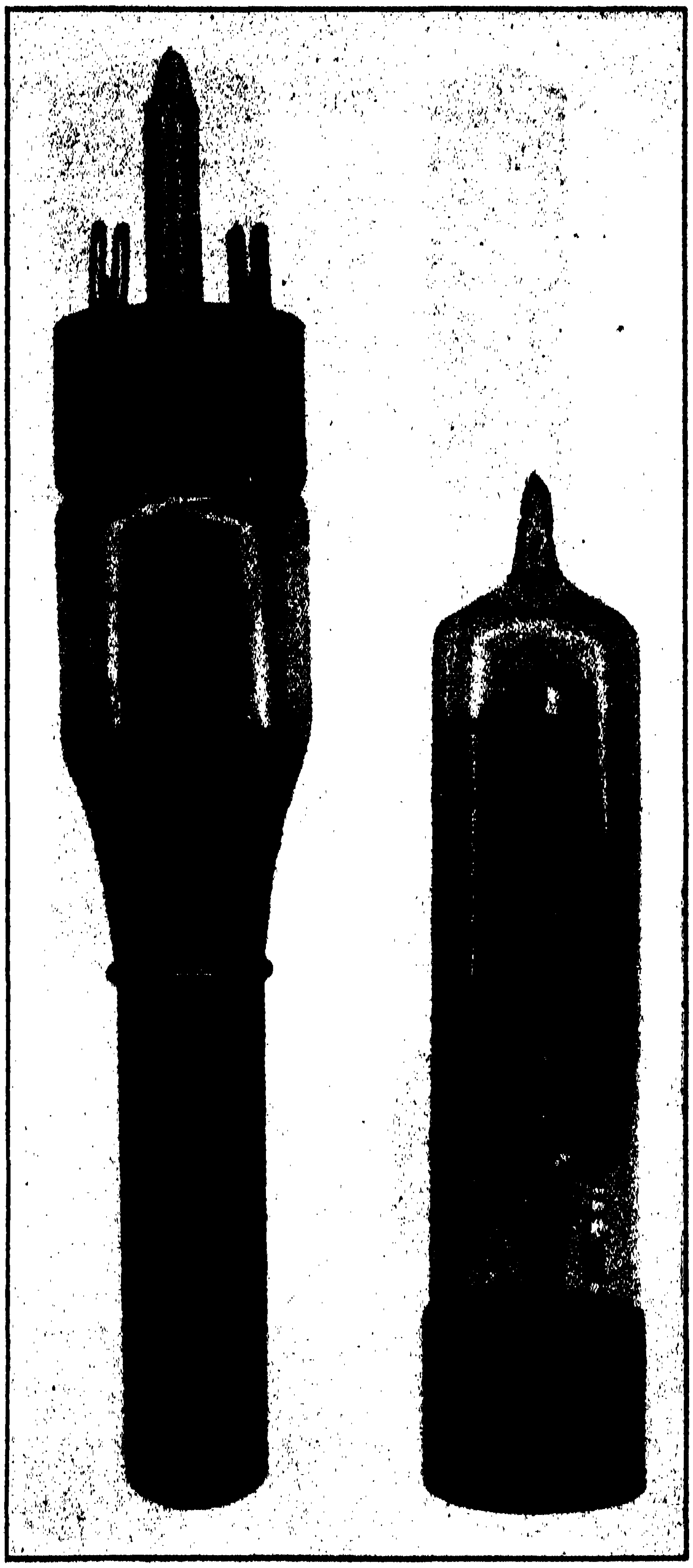

FIG. 8. THE TRANSATLANTIC VACUUM TUBE OF 1927

CONTRASTED WITH THAT OF 1915. THE TUBE ON THE LEFT IS THAT BEING USED TO-DAY, AND ALTHOUGH VERY LITTLE LARGER THAN THE ORIGINAL TUBE ON THE RIGHT, IT IS 400 TIMES AS POWERFUL.

At Rocky Point the journey by radio begins, and if atmospheric conditions are

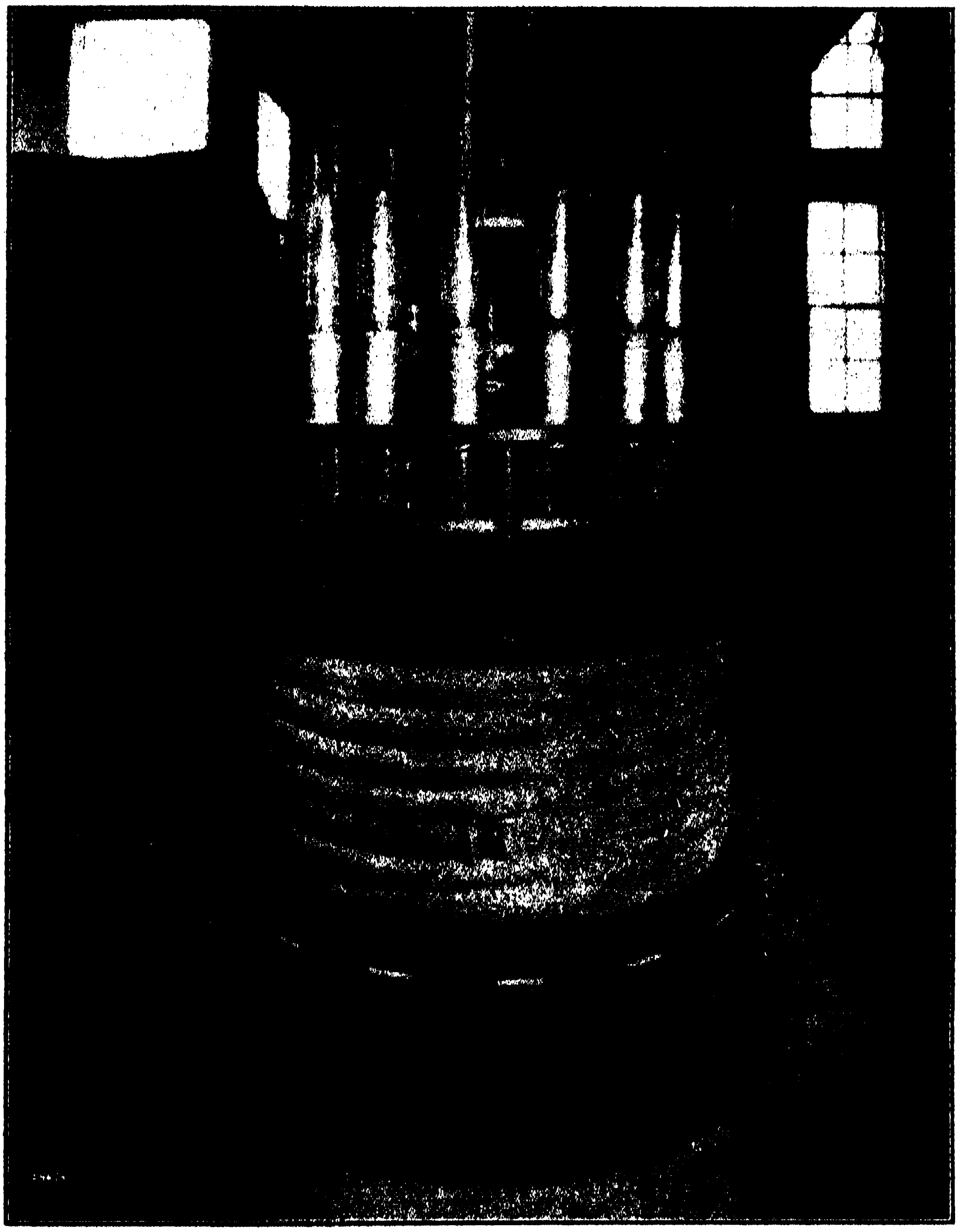

FIG. 9. WATER-COOLED POWER AMPLIFIER TUBES FOR TRANSATLANTIC RADIO TELEPHONY

not too unfavorable, will terminate successfully at Wroughton, England.[2] Here it is received and automatically relayed to a telephone line running to London and terminating in the long-distance headquarters there, from whence it goes by an ordinary telephone circuit to the British subscriber who may be anywhere in England, Wales or Scotland. As the Britisher speaks, his voice comes back over the same wires to London and thence over another telephone circuit to the town of Rugby, where the English radio transmitter is located. Here it undergoes enormous amplification, similar to that at Rocky Point, and is ready for the radio journey westward which terminates in the American receiving station located at Houlton, Me.

As previously mentioned, our experience shows that a receiving station located pretty well north is in a favorable position, and although every part of the British Isles lies north of Houlton,

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[2] The new British receiving station at Cupar. Scotland, went into service in May, 1927.

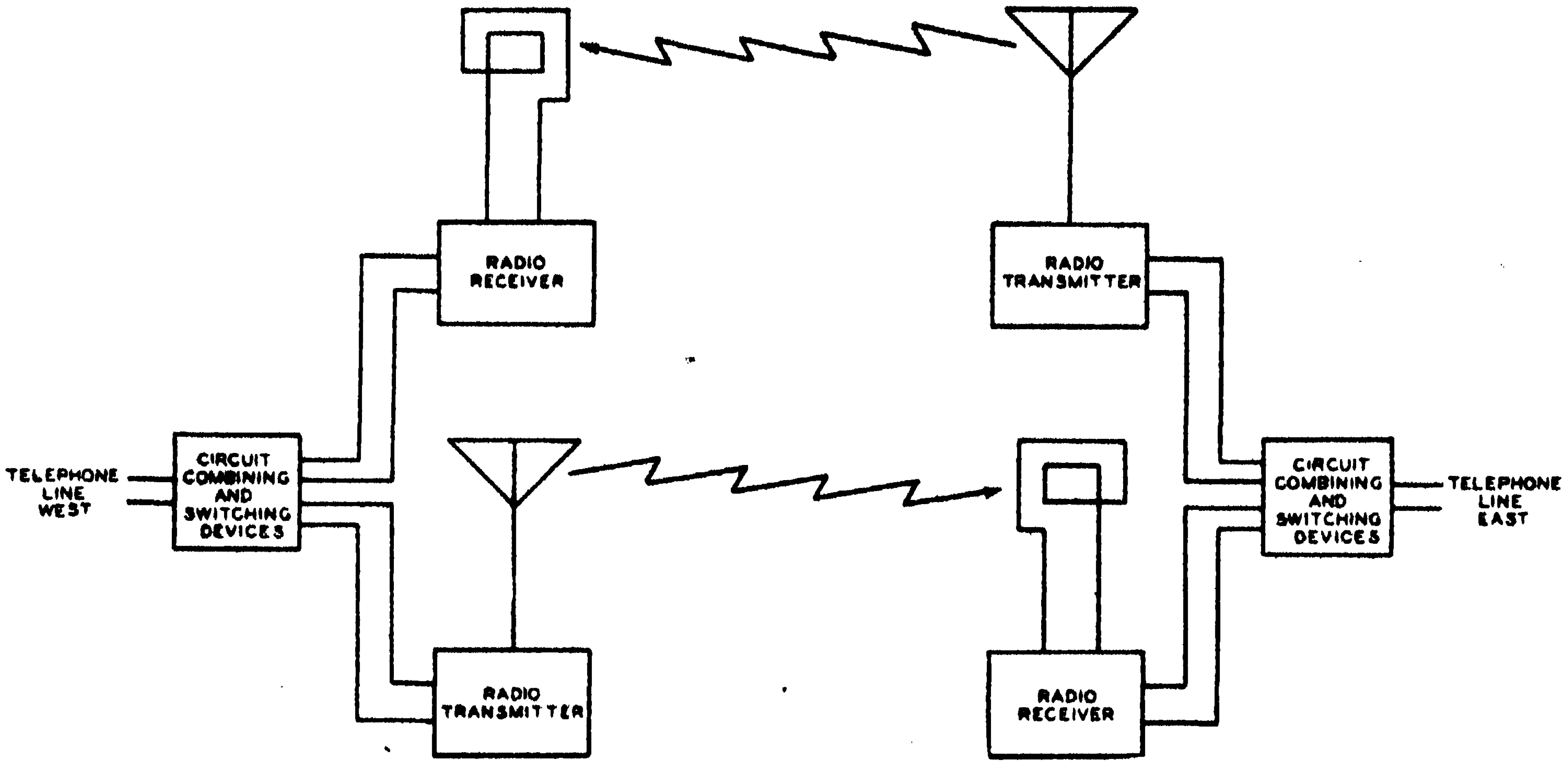

FIG. 10. DIAGRAM OF THE AMERICAN RECEIVING STATION TUNED TO THE WAVE-LENGTH OF THE TRANSMITTING STATION.

the English are now erecting a new receiver in the north of Scotland.[3] From Houlton the message comes down over an ordinary telephone line to New York, and thence to the western subscriber.

Figure 7 shows a view of one of the long-distance switchboards in New York. Except for little labels in the frames at the top of this board, there is nothing to indicate that the messages being handled here go to England rather than to Albany or Syracuse. Three of the girls shown, however (those at positions 103, 104 and 105), are the so-called transatlantic operators. The center girl of the three operates the radio branch of the circuit, that is, she is in touch with a corresponding "telephonist" as the English call their operators in London. The other two girls are responsible for the recording of calls, the looking up of telephone numbers of persons who are called, and the setting up of the necessary wire circuits in this country to connect the subscriber with the radio link. A similar pair of girls are stationed in London for taking care of analogous duties there.

The success of the transatlantic service depends, in large measure, upon the high power vacuum tubes we have perfected. Figure 8 gives an interesting epitome of power tube progress during the interval separating our first talk across the Atlantic in 1915 and the present. On the right is a sample of the tube we used in 1915; five hundred of these were operated as a single unit. On the left is the water-cooled tube of the present day, one of which is equivalent to 400 of the early tubes. About twenty water-cooled tubes are now used regularly and, therefore, supply some fifteen times the total power output available during our 1915 experiments and, of course, much more reliably. Figure 9 shows one of the amplifiers in which the present water-cooled tubes are used.

The girls who operate the transatlantic circuit have already been mentioned, but in a sense, the voice of anyone speaking over the transatlantic circuit is its own telephone operator, for there is at each terminus a little device so sensitive that the voice in passing through it throws it from one position into another and thereby accomplishes a most important result. Because of the limited number of wave-lengths available for transatlantic radio service, it is desirable to transmit the voice eastward on the same wave-length that we use for transmitting it westward. Referring to

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[3] See preceding footnote.

Figure 10, that means that the American receiving station is tuned to the wavelength on which the American transmitting station is sending. Now the former must normally be in such adjustment as to receive the very faint signals coming from Rugby, but standing as it does relatively close to the American transmitting station, it would, save for special arrangements to the contrary, pick up very strong speech signals coming from this nearby station—signals so strong that they would virtually overpower the receiving circuit. Exactly the same situation would arise at the English terminus and for the same reason.

It is to prevent this that the voice as it travels over the circuit is called upon to effect a sort of switching operation. In Figure 10 two points are indicated at which switches are capable of connecting the subscriber's line, either to the transmitting station (talking condition) or to the receiving station (listening position). Now in the unexcited or quiescent condition, the two receiving lines are operative, that is, the switches are thrown so as to connect them to the subscriber's lines, while the two transmitting circuits are disconnected. It is these switches that the voices of the speakers operate. Suppose the American subscriber speaks. As soon as his voice reaches the long-distance headquarters in New York City a portion of it is caused to pass through a sensitive relay which thereupon operates. This relay moves the switch from the receiving to the transmitting position. Therefore, when the same voice emerges from its radio transmitter tremendously amplified, it finds the path back to New York along the receiving line blocked, since this line has been disconnected. After traversing the ocean it can enter the English receiving circuit since this is in its normal operative condition, and so travels to the English subscriber.

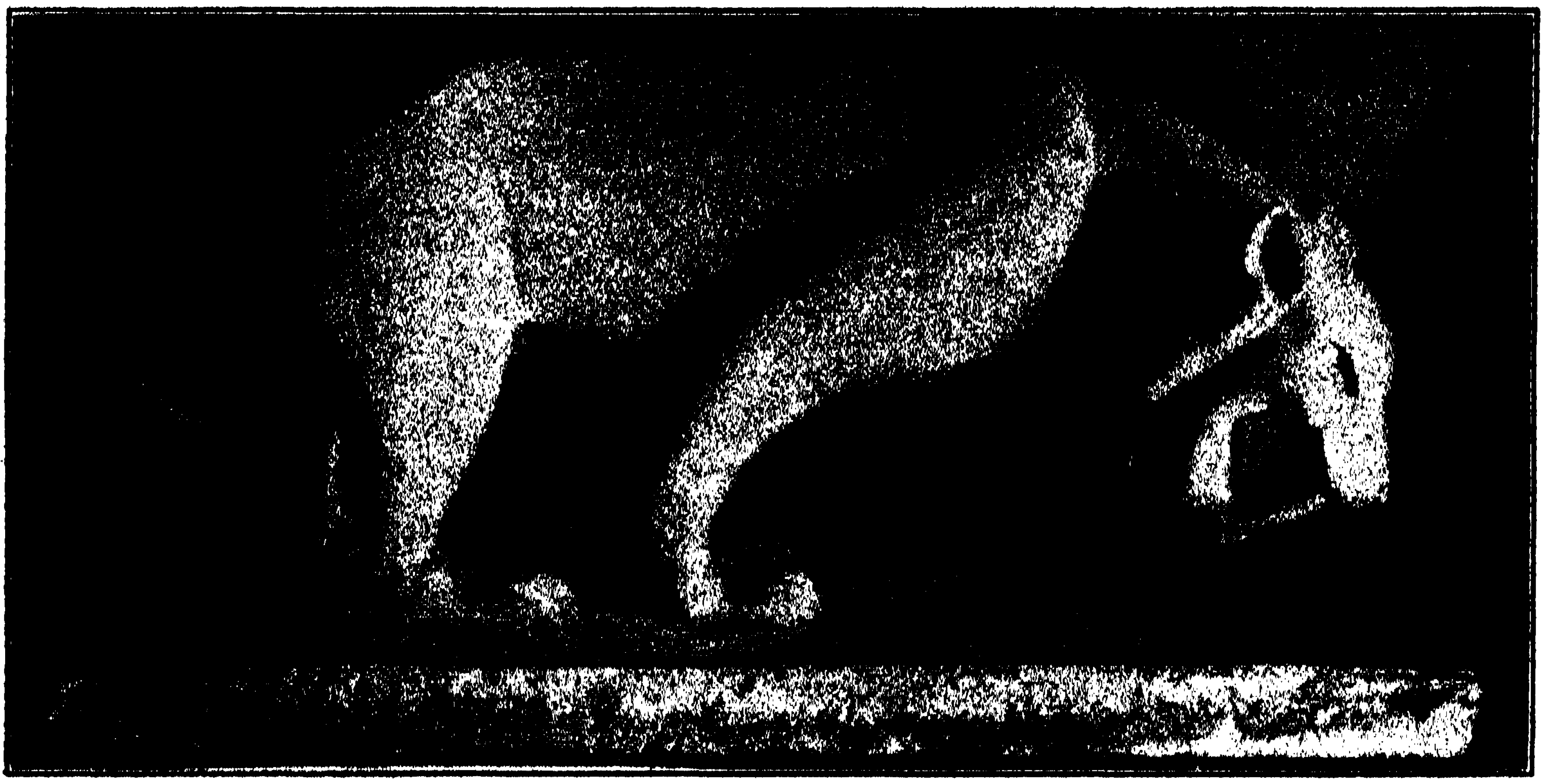
When the American subscriber ceases, his switch falls back to the receiving position, and as the English subscriber speaks, his switch is thrown from the receiving to transmitting position. His apparatus, therefore, can not pick up his own voice, but it can be picked up by the American receiving circuit, which became operative as soon as the American subscriber ceased speaking.

I shall conclude now, mentioning just one more thing that the voices of the speakers must do. Although they are not shown in the figure, there are similar relays in the two receiving circuits whose function is to make the complete system interlocking in the sense that when one subscriber is speaking, the other can not interrupt him. Thus so long as the relay in the English receiving line is under the influence of the American subscriber's voice, it locks the switch shown in the slide in the receiving position. Of course, this "lock" is immediately removed once the speaker stops, so that, so far as the subscribers are concerned, the circuit displays no inertia or delay.

I have attempted to describe in simple terms some of the rather remarkable things the telephone engineer can do with the devices that science has made possible, and, as a final word, I wish to quote a few lines from an old poem of Emerson's:

The lightning has run masterless too long;
He must to school and learn his verb and noun
Teaching his nimbleness to earn his wage,
Spelling with guided tongue man's messages.

In view of the details of operation of the transatlantic telephone, I believe you will agree with me that the lightning is making a very apt pupil.



THE SABER-TOOTH TIGER

By W. A. SPALDING

LOS ANGELES, CALIFORNIA

Before the age of ice had come,
  Before its glaciers planed the earth,
Before the streams were frozen dumb,
  Before the race of man had birth,

When this was still a tropic land,
  And trees and shrubs and plants were rank,
And water stood on every hand,
  With giant reptiles on the bank;

When mollusks bred in countless hordes,
  And strange, weird fishes swam the sea,
And saurians were winged, like birds,
  And mammoth lizards sported free;

And birds were few, and oft appeared
  As animals bereft of flight,
And giant sloths on haunches reared,
  And giant bats possessed the night—

Then roamed the saber-tooth at will;
  The terror of the jungle, he;
Armed as no other beast to kill,
  Fierce as no other beast could be.

The elephant imperial, tall;
  The mastodon of ponderous weight;
The sloth, full-armored over all—
  Were helpless victims doomed of fate.

Fate and the saber-tooth were one,
  Asserting undisputed sway;
For evolution, just begun,
  Was strong and cruel in that day.

But nature, from her fearsome first,
  Brought recompense for evils all,
And utilized her lowest, worst,
  To work her ends—to bring their fall.

And nature hath her quiet ways,
  The fierce and strong to overmatch;
And nature watches nights and days,
  And nature's trap is set to catch:

A quiet pool in shady nook,
  A cool, inviting solitude,
Thence running forth a little brook,
  Meandering seaward through the wood;

But, on the basin's shallow floor,
  And reaching forth beyond its brink,
An oily ooze—who ventures o'er
  Must flounder here, and sink.

And hither come the foolish herd—
  The small and weak, the great and strong—
By fate of others undeterred,
  In purblind urge they march along.

And hither comes the tiger, too,
  Attracted by their frightened cry—

* * * * * * *

But that was eons-gone ago—
  In asphalt-bond their fossils lie.

THE PROGRESS OF SCIENCE

EDITED BY DR. EDWIN E. SLOSSON

Director of Science Service

HOW BIG CAN A STAR BE?

THE first star to be measured five years ago, Betelgeuse, proved to be so large that it quite cast our own sun in the shade, speaking metaphorically. For its volume is some fifty million times that of the sun. But if we compare mass instead of measure we need not feel so much ashamed of the bright particular star to which we are attached. For if the two stars could be put into balance pans, Betelgeuse would be only some fifty times heavier than our sun. If now we divide the weight, 50,000,000, by volume, 50, we find that the average density, or specific gravity, of Betelgeuse is about a million times less than that of the sun. This red giant star is therefore a mere gas-bag—minus the bag. In fact its atmosphere is so thin that it resembles the attenuated gas that we call the "vacuum" of our electric light bulbs or radio tubes.

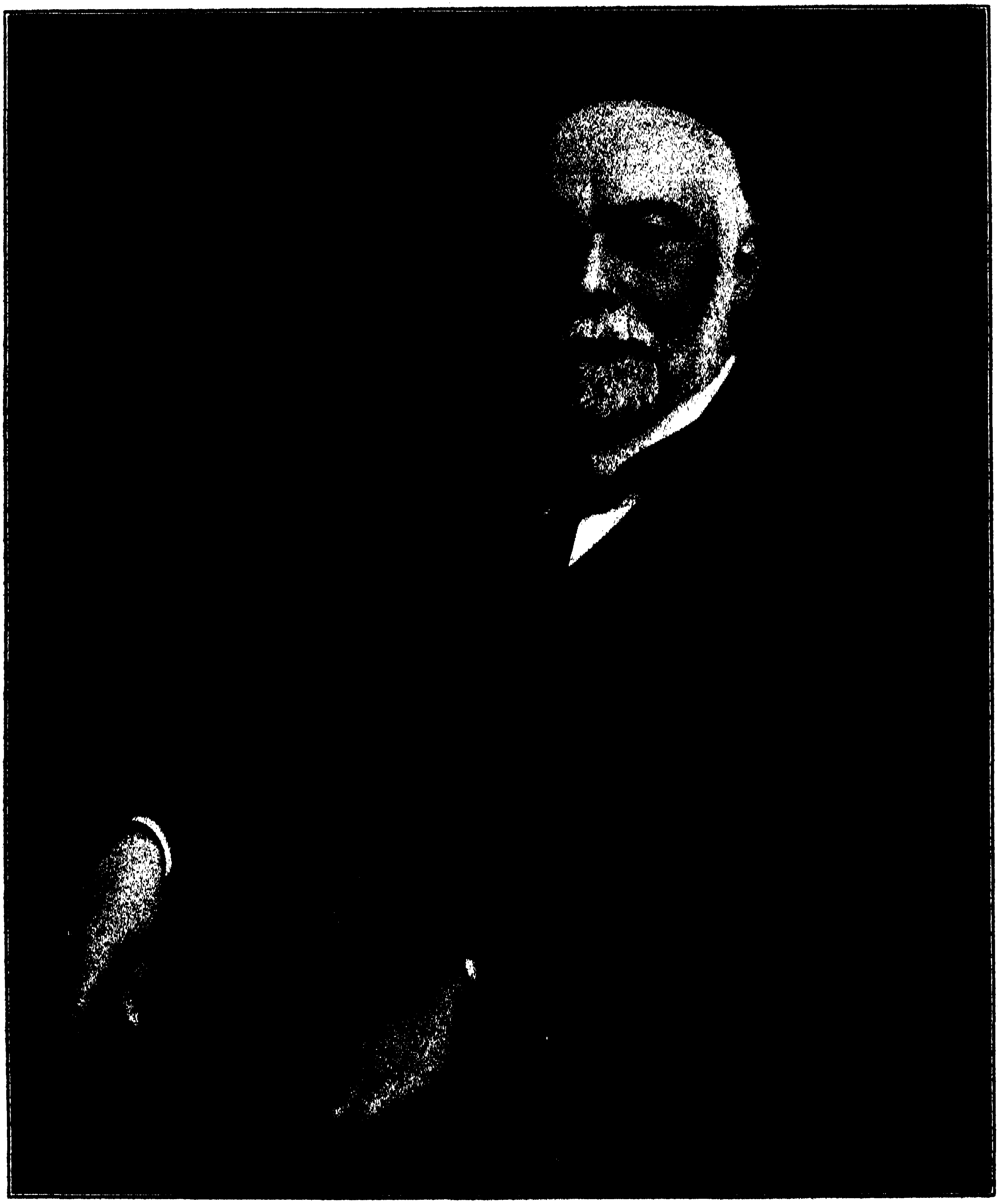
Stars differ vastly in volume but not so much in mass. The astronomer can not find any that is very many times heavier than Betelgeuse. And he wonders why. Might there not exist a star that would be fifty million times as heavy as well as fifty million times as big as the sun?

"No," says Einstein. For if there were, it would upset his law of gravitation. Professor Eddington, of Cambridge, in his new book, "The Internal Constitution of the Stars," gives three reasons why the relativity theory sets a limit to the conceivable size of visible stars. First, because light acts as though attracted by large masses of matter, and the force of gravitation of such a massive sphere would be so great that the rays of light could not get away from its surface. They would fall back to the star like a stone to the earth. Second, it has been found that the spectral lines of light from a heavy shining body, like a star, is shifted toward the red end of the spectrum, and, in the case of a giant star as dense as the sun, all the lines would be shifted so far that the spectrum would go out of existence. Third, according to Einstein, a heavy body somehow crumples up space in its vicinity, and so immense a mass of matter as we are imagining would be sufficient to close up the space around the star and leave us shut outside of the universe; that is to say, nowhere.

This reminds me of a big bedfellow I used to bunk with who would wrap the blankets close about him and leave me out in the cold. Also it reminds me of a rat I was told about when I was a boy, which could never be caught, for when he ran into a hole he pulled the hole in after him.

Professor Eddington evidently anticipates that his argument may arouse surprise or skepticism for he says that lest it be "regarded as ultra-modern by more conservative readers," he hastens to add, that Laplace, founder of modern astronomy, arrived, over a century ago, at a similar conclusion, that a star of such mass would be too big to be seen and "it is therefore possible that the largest luminous bodies in the universe may, through this cause, be invisible."

Anyhow it's nice to know that no star can grow so large, through the merger of other stellar systems, that it will monopolize the universe and crowd the rest of us out of space and time.



FREDERICK BELDING POWER

In charge of the Phytochemical Laboratory of the Bureau of Chemistry of the United States Department of Agriculture from 1816 until his death; previously, for eighteen years, director of the Wellcome Chemical Research Laboratories, London

THE UNSEEN LIFE OF THE SOIL

UNSEEN and unknown to almost every one, invisible because of their microscopically small size and always hidden in subterranean darkness, there is a whole swarming world of life under our feet. Its members are often weird in form, sometimes beneficent, sometimes harmful in their acts, but never for a moment, day or night, without their effect on the giant world of plants and animals and men that lives forgetfully above them.

This world of the soil microbiota, forgotten or ignored by all save a relative handful of scientists scattered over the earth, was outlined before the First International Congress of Soil Science, held in Washington, by Sir John Russell, director of the oldest and greatest agricultural experiment station in the world, at Rothamsted, England.

The effects wrought by soil bacteria, fungi, protozoa and other forms of life are manifold. Lowly plants called algae capture carbon dioxide from the air, build it into their bodies, and eventually, when they die, release their organic substances as humus for the enrichment of the soil. Many kinds of soil bacteria, both free-living and associated with other plants, are able to capture the otherwise inert and useless nitrogen gas from the air, which is eventually turned by the higher plants into meat-making proteids.

Bacteria break down dead plant and animal bodies, returning them to the dust from which they came; if it were not for this activity, the earth's surface would soon be cumbered with carcasses, with all the material basis of life locked up in them beyond recovery. This process is not a simple one, carried on by only one class of bacteria.

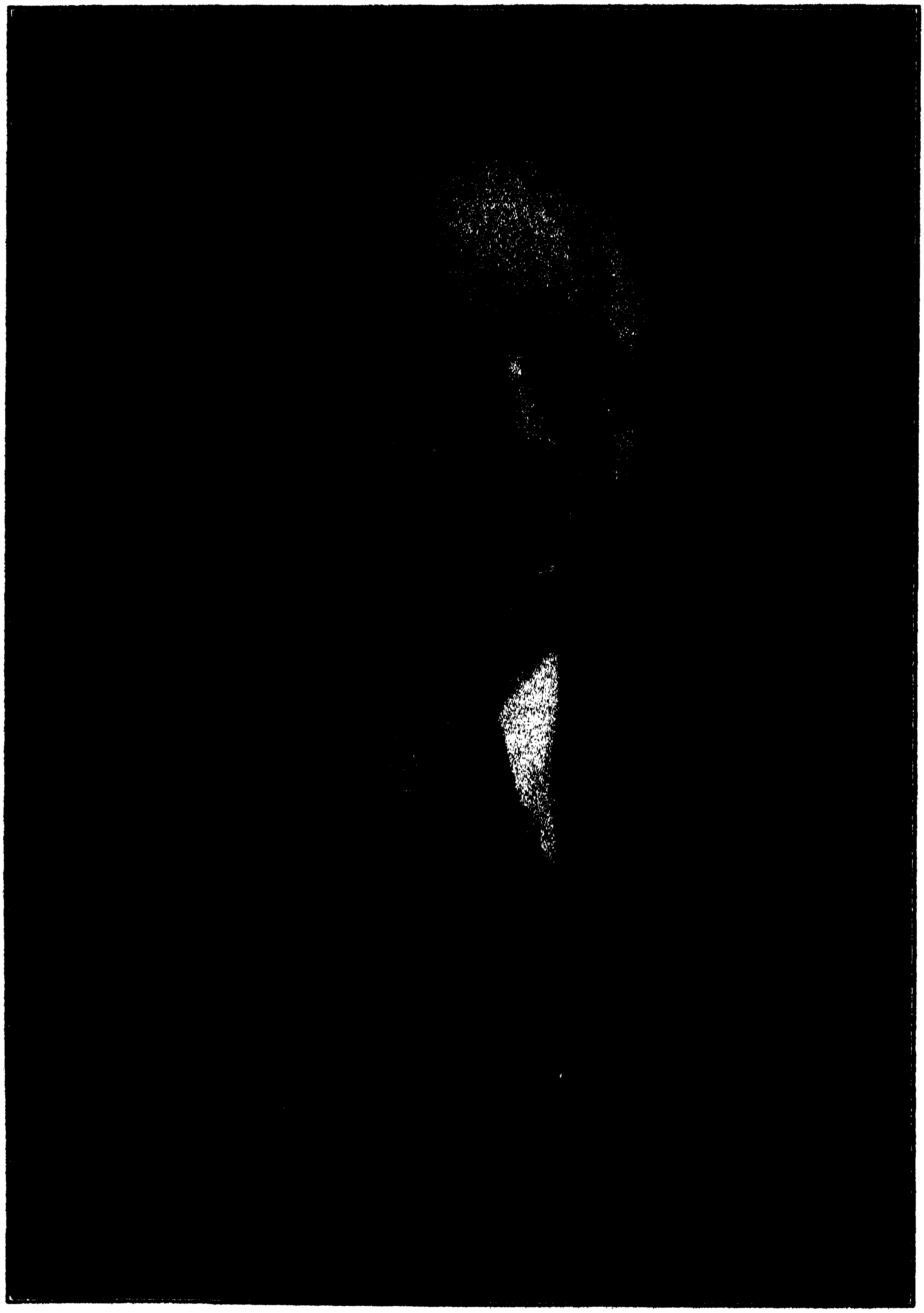
One gang of these microscopic wreckers goes to work, carries the process as far as its nature permits, and then quits. Another takes its place, forwards the work another stage, and in its turn passes it on to still other groups. At last the complex substances of the dead body are again the simple compounds that plants can use, and the upbuilding process begins once more.

Tearing down is as important a process in the cycle as setting up; for there are only just so many bricks for life to build with, and they must be used over and over. These lowly creatures of the soil, which may be our own unrecognized evolutionary ancestors, do the cosmos a service by plucking down our abandoned dwellings so that our descendants may make houses for themselves.

THE breath of bacteria, the carbon dioxide discarded by them as a by-product of their life-processes, comes to man's table as his daily bread. We live on the exhalations of billions of tiny beings which we never see. This, in brief paraphrase, is the revolutionary doctrine laid before the First International Congress of Soil Science, held in Washington, by Dr. Julius Stoklasa, of the Technical Institute and Experiment Station of Prague, recognized as one of the leading authorities in the world on the difficult science of plant nutrition.

The old theory that plants build their food out of carbon dioxide which they capture from the air by means of their leaves, Dr. Stoklasa said, is entirely inadequate. The supplies of this gas in the air, according to his measurements, are not sufficient to account for the sugars, starches and other substances formed by plants with the assistance of the sun's energy. But the soil solution contains a great deal of carbon in the form of bicarbonates, and this carbon is taken into the plant along with the other soil minerals used by the plant, and borne by the sap to the green parts where carbohydrate manufacture is going on.

The amounts of carbon taken in from



CARL H. EIGENMANN

Professor of zoology in the University of Indiana from 1891 until his death, distinguished for his work in ichthyology, more especially in the freshwater fishes of tropical America.

the soil, Professor Stoklasa asserted, compare in quantity with the amounts of other minerals assimilated. Thus, for every hundred pounds of carbon so absorbed, 154 pounds of nitrogen, 113 pounds of phosphoric acid, 106 pounds of potash, 33 pounds of calcium oxide and 26 pounds of magnesium oxide are taken in. This indicates a hitherto little suspected and wholly unmeasured part played by carbon dioxide in the soil.

Of course not nearly all of the carbon dioxide given off by soil bacteria gets into the plants. A great deal of it escapes upwards, into the air. But here the leaves are waiting for it, and it passes into the plants through the channels hitherto taught as orthodox according to the accepted doctrines of plant physiology. Furthermore, according to Professor Stoklasa, fertilizers added to the soil are by no means entirely for the direct benefit of the corn or clover or other crops. A large share of these plant condiments fall to the share of the bacteria, stimulating them to greater activity in the production of materials eventually used in the production of foods by the higher plants.

THE CONTRIBUTION OF SCIENTIFIC MEN TO AMERICAN INDEPENDENCE

THE one hundred and fifty-first anniversary of the United States as an independent nation reminds us of the part taken by scientific men in the establishment of the Republic. Of the five members of the committee that drafted the Declaration of Independence, three were scientists. The young statesman who composed it—Thomas Jefferson—also wrote what has been called America's "declaration of scientific independence." The veteran diplomat who corrected the original draft—Benjamin Franklin—was heaped with honors as one of the leading scientists of his time. The first man to vote for freedom on that first Fourth of July, in 1776, later founded a state scientific society and served as its first president. And other scientists were among the patriots of the Continental Congress who risked their lives to sign the Declaration.

These striking facts are brought out by private correspondence and published records which show that the founders of the nation were bold thinkers along other than political lines. Dr. Charles E. Munroe, of the U. S. Bureau of Mines, the leading authority on explosives in this country, has found papers showing that Benjamin Franklin was the first to suggest a practical system of firing gunpowder by electricity. To-day, throughout the world, blasting operations are almost universally fired in a similar manner. This is but another item in the long list of scientific achievements of this versatile man. Inventor of the lightning rod, rotary printing press, bifocal glasses, the Franklin stove, and many other things, Franklin was no less great in pure science. Only in recent years has it been realized how nearly correct were his views of the nature of electricity. And he was the first to show how storms and other weather phenomena move across the country. Such knowledge to-day makes possible the work of the Weather Bureau.

But as a great scientist of history, Franklin has a close rival. Thomas Jefferson was hardly less of a scientist. Many devices for saving labor on the farm were his invention. One was an improved plow, the first to turn the earth over as well as to break it up. But in 1782, he published America's declaration of scientific independence. This was the famous "Notes on Virginia." In it he completely refuted the idea of Count

PROFESSOR LIGHTNER WITMER

And his assistants making an examination in the Psychological Clinic of the University of Pennsylvania, at the time of the celebration of the thirtieth anniversary of the clinic.

de Buffon, eminent French zoologist, that American animals were smaller and represented fewer species than those of Europe. And to clinch his arguments, he sent over to the count many boxes of bones of living and extinct American animals. His chief interest was paleontology, study of the remains of extinct creatures. One of his discoveries was the one he called "Megalonyx" or "Great Claw," a prehistoric American fossil that has since been identified as a giant sloth. It is still called "Megalonyx jeffersoni."

Among the other members of the committee of five that drafted the Declaration, Roger Sherman can also be classed as a scientist. He made astronomical calculations for an almanac and made mathematics his hobby. Dr. Josiah Bartlett, first to vote for the Declaration, and first to sign it after President Hancock, later organized the New Hampshire State Medical Society and was its first president. Four other physicians signed the Declaration. At least one, Benjamin Rush, has won enduring fame in scientific annals. He was the first to study mental diseases in the United States. He inquired into the hereditary nature of drunkenness, the effect of decayed teeth on other parts of the body, and the effect of the body glands.

As our country has always, in time of stress, turned to its scientists for aid, so was the very origin of our country associated with men of scientific interests.

ALESSANDRO VOLTA

VOLTA died in Como a century ago, and the town on the beautiful Lake of Como is commemorating the centennial by an international exposition of electricity from May to October. The Italian Government has cooperated in the memorial through the issuance of postage stamps and the contribution of liberal funds. America will participate in the centennial through representation by a committee formed by the Italy-America Society and the International Electrical Commission, which hopes to announce at Como a fellowship giving a year's study in the United States to an Italian electrical engineer.

A sketch of the life of Volta, printed in the New York *Times*, tells us that he was born in Como in 1745. He was interested in physics and chemistry as a boy. During his professorship in the Royal School at Como, and the quarter of a century during which he held the chair of physics at Pavia, he discovered the organic nature of marsh gas and devised many experiments in atmospheric electricity, such as igniting gases by electrical sparks in enclosed vessels.

Of Volta's many discoveries the most dramatic was the "voltaic pile," an instrument which was used to decompose water into hydrogen and oxygen. Galvani's discovery of animal electricity led Volta to experiment with two different metals in contact, and by the use of his condensing electroscope he virtually proved his theory that the action of the current was due to the two metals.

Volta developed his electric pile of two dissimilar metals, such as zinc and copper, in contact, separated from a corresponding pair by paper or cloth soaked in weak brine. To this he added the "crown of cups," or first voltaic battery, in which strips of metal were placed in cups containing brine or weak acid. Scientists at first were divided over accepting his theories, but in the end Volta's ideas triumphed.

One of the first countries to give recognition to Volta's discoveries was Great Britain, where in 1791 the Royal Society awarded him the Copley Medal. Davy, head of the Royal Institution of London, took an interest in Volta's work and had

ALESSANDRO VOLTA

constructed a large pile consisting of several hundred disks. By this means he succeeded in isolating for the first time the metals sodium and potassium.

Napoleon, who in 1801 had summoned Volta to Paris to repeat for French savants his more important experiments, was indignant with the Academie des Sciences because the French had not made the discovery before Davy announced it. They replied that the English physicists succeeded because the funds had been furnished them for the construction of a huge voltaic pile. Napoleon provided funds for research and the French built a pile of their own. Napoleon went to inspect it shortly afterward, and to the astonishment of the custodians of the apparatus he seized the two terminals and placed them on his tongue before he could be prevented. He received a shock which rendered him speechless.

The English scientists made further use of Volta's discovery by raising public funds for the construction of an unusually large pile consisting of 2,000 pairs of plates. The first experiment made with this resulted in the production of electric arc light between two carbon poles in the laboratories of the Royal Institution.

Volta was made director of the philosophical faculty of Padua by the Emperor of Austria in 1815, but held the post only four years when he resigned to spend the remander of his days in Como. Napoleon honored him with the title of count and senator of the kingdom of Lombardy, and had a medal struck for him. Commemorative of the discovery of the voltaic cell, a centennial exposition was held in Como in 1899 with unfortunate results. During its progress a number of valuable Volta relics and manuscripts were destroyed by fire.

THE TOTAL ECLIPSE OF THE SUN

THE total eclipse of the sun that occurred on June 29 was not favorable for scientific observations as it was early in the morning, of short duration and in regions where the weather was not likely to be favorable. It was, however, of much popular interest, especially in England, where there has been no total eclipse since 1724 and will not be another until 1999, then only just touching the southwestern tip of Cornwall. It was mostly raining or cloudy in England, Manchester having sent the characteristic report "The sun here was eclipsed as usual."

While the phenomenon was obscured by rain, mists and clouds in most parts of the country, Giggleswick, where Sir Frank Dyson, astronomer royal, was stationed with the Royal Observatory expedition, enjoyed a perfect view during the period of totality. It was rare good fortune for, up to three minutes before the eclipse began, the sky there too was obscured by clouds which returned almost as soon as it was over and rain fell.

There were three official British astronomical expeditions, in addition to that of Sir Frank Dyson. One, under Major Lockyer, of the Sidmouth Observatory, was stationed at Richmond, Yorkshire; another, under Professor H. H. Turner and Dr. Knox Shaw, of Oxford, was at Southport, while the third, under Professor H. P. Newall, of Cambridge, went to Aal, Norway.

Cloudy weather prevailed at Fagernes, north of Oslo, and at Aal, preventing successful observations by the American astronomical expeditions gathered there. In the American party at Fagernes were Professor S. A. Mitchell, director of the Leander McCormick Observatory of the University of Virginia, and Professor

—*From Punch*

Vicar.—"I FIND OUR ANNUAL GARDEN FETE IS FIXED FOR THE SAME DAY AS THE ECLIPSE. I THINK I MUST GET IT PUT OFF."

Gardener.—"YOU COULDN'T 'ARDLY DO THAT, SIR—NOT A *total* ECLIPSE YOU COULDN'T."

Harlan T. Stetson, of Harvard University.

At Ringebu, in Gudbrandsdal, however, and at Nyborgmön, in Finmark, weather conditions were perfect and excellent observations were made and photographs taken by the Norwegian Professors Säland and Vegard at the former, and by the German Professor Linke and M. Krogness, director of the Geophysical Institute of Tromsö at the latter.

THE SCIENTIFIC MONTHLY

SEPTEMBER, 1927

THE INTERDEPENDENCE OF SCIENCE AND MEDICINE[1]

By the Late LORD LISTER

I HAVE first to express my deep sense of gratitude for the great honor conferred upon me by my election to the high office which I occupy to-day. It came upon me as a great surprise. The engrossing claims of surgery have prevented me for many years from attending the meetings of the association, which excludes from her sections medicine in all its branches. This severance of the art of healing from the work of the association was right and indeed inevitable. Not that medicine has little in common with science. The surgeon never performs an operation without the aid of anatomy and physiology; and in what is often the most difficult part of his duty, the selection of the right course to follow, he, like the physician, is guided by pathology, the science of the nature of disease, which, though very difficult from the complexity of its subject-matter, has made during the last half-century astonishing progress; so that the practice of medicine in every department is becoming more and more based on science as distinguished from empiricism. I propose on the present occasion to bring before you some illustrations of the interdependence of science and the healing art; and the first that I will take is perhaps the most astonishing of all results of purely physical inquiry—the discovery of the Röntgen rays, so called after the man who first clearly revealed them to the world. Mysterious as they still are, there is one of their properties which we can all appreciate—their power of passing through substances opaque to ordinary light. There seems to be no relation whatever between transparency in the common sense of the term and penetrability to these emanations. The glasses of a pair of spectacles may arrest them while their wooden and leather case allows them to pass almost unchecked. Yet they produce, whether directly or indirectly, the same effects as light upon a photographic plate. As a general rule, the denser any object is, the greater obstacle does it oppose to the rays. Hence, as bone is denser than flesh, if the hand or other part of the body is placed above the sensitive film enclosed in a case of wood or other light material at a suitable distance from the source of the rays, while they pass with the utmost facility through the uncovered parts of the lid of the box and powerfully affect the plate beneath, they are arrested to a large extent by the bones, so that the plate is little acted upon in the parts opposite to them, while the portions corresponding to the muscles and other soft parts are influenced in an intermediate degree. Thus a picture is obtained in which the bones stand out in sharp relief among the flesh, and anything abnormal in their shape or position is clearly displayed.

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[1] Address by the President of the British Association for the Advancement of Science, given at the Liverpool meeting of 1896.

I need hardly point out what important aid this must give to the surgeon. As an instance, I may mention a case which occurred in the practice of Mr. Howard Marsh. He was called to see a severe injury of the elbow, in which the swelling was so great as to make it impossible for him by ordinary means of examination to decide whether he had to deal with a fracture or a dislocation. If it were the latter, a cure would be effected by the exercise of violence, which would be not only useless, but most injurious, if a bone was broken. By the aid of the Röntgen rays a photograph was taken in which the bone of the upper arm was clearly seen displaced forwards on those of the forearm. The diagnosis being thus established, Mr. Marsh proceeded to reduce the dislocation; and his success was proved by another photograph which showed the bones in their natural relative position.

The common metals, such as lead, iron and copper, being still denser than the osseous structures, these rays can show a bullet embedded in a bone or a needle lodged about a joint. At the last conversazione of the Royal Society a picture produced by the new photography displayed with perfect distinctness through the bony framework of the chest a halfpenny low down in a boy's gullet. It had been there for six months, causing uneasiness at the pit of the stomach during swallowing; but whether the coin really remained impacted, or, if so, what was its position, was entirely uncertain till the Röntgen rays revealed it. Dr. Macintyre, of Glasgow, who was the photographer, informs me that when the presence of the halfpenny had been thus demonstrated, the surgeon in charge of the case made an attempt to extract it, and although this was not successful in its immediate object it had the effect of dislodging the coin; for a subsequent photograph by Dr. Macintyre not only showed that it had disappeared from the gullet, but also thanks to the wonderful penetrating power which the rays had acquired in his hands, proved that it had not lodged further down in the alimentary passage. The boy has since completely recovered.

The Röntgen rays cause certain chemical compounds to fluoresce, and emit a faint light plainly visible in the dark; and if they are made to fall upon a translucent screen impregnated with such a salt, it becomes beautifully illuminated. If a part of the human body is interposed between the screen and the source of the rays, the bones and other structures are thrown in shadow upon it, and thus a diagnosis can be made without the delay involved in taking a photograph. It was in fact in this way that Dr. Macintyre first detected the coin in the boy's gullet. Mr. Herbert Jackson, of King's College, London, early distinguished himself in this branch of the subject. There is no reason to suppose that the limits of the capabilities of the rays in this way have yet been reached. By virtue of the greater density of the heart than the adjacent lungs, with their contained air, the form and dimensions of that organ in the living body may be displayed on the fluorescent screen, and even its movements have been lately seen by several different observers.

Such important applications of the new rays to medical practice have strongly attracted the interest of the public to them, and I venture to think that they have even served to stimulate the investigations of physicists. The eminent professor of physics in the University College of this city (Professor Lodge) was one of the first to make such practical applications, and I was able to show to the Royal Society at a very early period a photograph, which he had the kindness to send me, of a bullet embedded in the hand. His interest in the medical aspect of the subject remains unabated, and at the same time he has been one of the most distinguished investigators of its purely physical side.

There is another way in which the Röntgen rays connect themselves with physiology, and may possibly influence medicine. It is found that if the skin is long exposed to their action it becomes very much irritated, affected with a sort of aggravated sunburning. This suggests the idea that the transmission of the rays through the human body may be not altogether a matter of indifference to internal organs, but may, by long-continued action, produce, according to the condition of the part concerned, injurious irritation of salutary stimulation.

This is the jubilee of anesthesia in surgery. That priceless blessing to mankind came from America. It had, indeed, been foreshadowed in the first year of this century by Humphry Davy, who, having found a toothache from which he was suffering relieved as he inhaled laughing gas (nitrous oxide), threw out the suggestion that it might perhaps be used for preventing pain in surgical operations. But it was not till, on September 30, 1846, Dr. W. T. G. Morton, of Boston, after a series of experiments upon himself and the lower animals, extracted a tooth painlessly from a patient whom he had caused to inhale the vapor of sulphuric ether, that the idea was fully realized. He soon afterwards publicly exhibited his method at the Massachusetts General Hospital, and after that event the great discovery spread rapidly over the civilized world. I witnessed the first operation in England under ether. It was performed by Robert Liston in University College Hospital, and it was a complete success. Soon afterwards I saw the same great surgeon amputate the thigh as painlessly, with less complicated anesthetic apparatus, by aid of another agent, chloroform, which was being powerfully advocated as a substitute for ether by Dr. (afterwards Sir James Y.) Simpson, who also had the great merit of showing that confinements could be conducted painlessly, yet safely, under its influence. These two agents still hold the field as general anesthetics for protracted operations, although the gas originally suggested by Davy, in consequence of its rapid action and other advantages, has taken their place in short operations, such as tooth extraction. In the birthplace of anesthesia ether has always maintained its ground; but in Europe it was to a large extent displaced by chloroform till recently, when many have returned to ether, under the idea that, though less convenient, it is safer. For my own part, I believe that chloroform, if carefully administered on right principles, is, on the average, the safer agent of the two.

The discovery of anesthesia inaugurated a new era in surgery. Not only was the pain of operations abolished, but the serious and sometimes mortal shock which they occasioned to the system was averted, while the patient was saved the terrible ordeal of preparing to endure them. At the same time the field of surgery became widely extended, since many procedures, in themselves desirable, but before impossible from the protracted agony they would occasion, became matters of routine practice. Nor have I by any means exhausted the list of the benefits conferred by this discovery.

Anesthesia in surgery has been from the first to last a gift of science. Nitrous oxide, sulphuric ether and chloroform are all artificial products of chemistry, their employment as anesthetics was the result of scientific investigation, and their administration, far from being, like the giving of a dose of medicine, a matter of rule of thumb, imperatively demands the vigilant exercise of physiological and pathological knowledge.

While rendering such signal service to surgery, anesthetics have thrown light upon biology generally. It has been found that they exert their soporific influence not only upon vertebrata, but upon animals so remote in structure from man as bees and other insects. Even the functions of vegetables are suspended by their agency. They thus afford strong confirmation of the great generalization that living matter is of the same essential nature wherever it is met with on this planet, whether in the animal or vegetable kingdom. Anesthetics have also, in ways to which I need not here refer, powerfully promoted the progress of physiology and pathology.

My next illustration may be taken from the work of Pasteur on fermentation. The prevailing opinion regarding this class of phenomena when they first engaged his attention was that they were occasioned primarily by the oxygen of the air acting upon unstable animal or vegetable products, which, breaking up under its influence, communicated disturbance to other organic materials in their vicinity, and thus led to their decomposition. Cagniard-Latour had, indeed, shown several years before that yeast consists essentially of the cells of a microscopic fungus which grows as the sweetwort ferments; and he had attributed the breaking up of the sugar into alcohol and carbonic acid to the growth of the micro-organism. In Germany Schwann, who independently discovered the yeast plant, had published very striking experiments in support of analogous ideas regarding the putrefaction of meat. Such views had also found other advocates, but they had become utterly discredited, largely through the great authority of Liebig, who bitterly opposed them.

Pasteur, having been appointed as a young man dean of the faculty of sciences in the University of Lille, a town where the products of alcoholic fermentation were staple articles of manufacture, determined to study that process thoroughly; and, as a result, he became firmly convinced of the correctness of Cagniard-Latour's views regarding it. In the case of other fermentations, however, nothing fairly comparable to the formation of yeast had till then been observed. This was now done by Pasteur for that fermentation in which sugar is resolved into lactic acid. This lactic fermentation was at that time brought about by adding some animal substance, such as fibrin, to a solution of sugar, together with chalk that should combine with the acid as it was formed. Pasteur saw, what had never before been noticed, that a fine gray deposit was formed, differing little in appearance from the decomposing fibrin, but steadily increasing as the fermentation proceeded. Struck by the analogy presented by the increasing deposit to the growth of yeast in sweetwort, he examined it with the microscope, and found it to consist of minute particles of uniform size. Pasteur was not a biologist, but although these particles were of extreme minuteness in comparison with the constituents of the yeast plant, he felt convinced that they were of an analogous nature, the cells of a tiny microscopic fungus. This he regarded as the essential ferment, the fibrin or other so-called ferment serving, as he believed, merely the purpose of supplying to the growing plant certain chemical ingredients not contained in the sugar, but essential to its nutrition. And the correctness of this view he confirmed in a very striking manner, by doing away with the fibrin or other animal material altogether, and substituting for it mineral salts containing the requisite chemical elements. A trace of the gray deposit being applied to a solution of sugar containing these salts, in addition to the chalk, a brisker lactic fermentation ensued than could be procured in the ordinary way.

I have referred to this research in some detail because it illustrates Pasteur's acuteness as an observer and his ingenuity in experiment, as well as his almost intuitive perception of truth.

A series of other beautiful investigations followed, clearly proving that all true fermentations, including putrefaction, are caused by the growth of microorganisms.

It was natural that Pasteur should desire to know how the microbes which he showed to be the essential causes of the various fermentations took their origin. It was at that period a prevalent notion, even among many eminent naturalists, that such humble and minute beings originated *de novo* in decomposing organic substances; the doctrine of spontaneous generation, which had been chased successively from various positions which it once occupied among creatures visible to the naked eye, having taken its last refuge where the objects of study were of such minuteness that their habits and history were correspondingly difficult to trace. Here again Pasteur at once saw, as if by instinct, on which side the truth lay; and perceiving its immense importance, he threw himself with ardor into its demonstration. I may describe briefly one class of experiments which he performed with this object. He charged a series of narrow-necked glass flasks with a decoction of yeast, a liquid peculiarly liable to alteration on exposure to the air. Having boiled the liquid in each flask, to kill any living germs it might contain, he sealed its neck with a blowpipe during ebullition; after which the flask being allowed to cool, the stream within it condensed, leaving a vacuum above the liquid. If, then, the neck of the flask were broken in any locality, the air at that particular place would rush in to fill the vacuum, carrying with it any living microbes that might be floating in it. The neck of the flask having been again sealed, any germs so introduced would in due time manifest their presence by developing in the clear liquid. When any of such a series of flasks were opened and re-sealed in an inhabited room, or under the trees of a forest, multitudes of minute living forms made their appearance in them; but if this was done in a cellar long unused, where the suspended organisms, like other dust, might be expected to have all fallen to the ground, the decoction remained perfectly clear and unaltered. The oxygen and other gaseous constituents of the atmosphere were thus shown to be of themselves incapable of inducing any organic development in yeast water.

Such is a sample of the many well-devised experiments by which he carried to most minds the conviction that, as he expressed it, "*la génération spontanée est une chimère,*" and that the humblest and minutest living organisms can only originate by parentage from beings like themselves.

Pasteur pointed out the enormous importance of these humble organisms in the economy of nature. It is by their agency that the dead bodies of plants and animals are resolved into simpler compounds fitted for assimilation by new living forms. Without their aid the world would be, as Pasteur expresses it, *encombré de cadavres.* They are essential not only to our well-being, but to our very existence. Similar microbes must have discharged the same necessary function of removing refuse and providing food for successive generations of plants and animals during the past periods of the world's history; and it is interesting to think that organisms as simple as can well be conceived to have existed when life first appeared upon our globe have, in all probability, propagated the same lowly but most useful offspring during the ages of geological time.

Pasteur's labors on fermentation have had a very important influence upon surgery. I have been often asked to speak on my share in this matter before a public audience; but I have hitherto refused to do so, partly because the details are so entirely technical, but chiefly because I have felt an invincible repugnance to what might seem to savor of self-advertisement. The latter objection now no longer exists, since advancing years have indicated that it is right for me to leave to younger men the practice of my dearly loved profession. And it will perhaps be expected that, if I can make myself intelligible, I should say something upon the subject on the present occasion.

Nothing was formerly more striking in surgical experience than the difference in the behavior of injuries according to whether the skin was implicated or not. Thus, if the bones of the leg were broken and the skin remained intact, the surgeon applied the necessary apparatus without any other anxiety than that of maintaining a good position of the fragments, although the internal injury to bones and soft parts might be very severe. If, on the other hand, a wound of the skin was present, communicating with the broken bones, although the damage might be in other respects comparatively slight, the compound fracture, as it was termed, was one of the most dangerous accidents that could happen. Mr. Syme, who was, I believe, the safest surgeon of his time, once told me that he was inclined to think that it would be, on the whole, better if all compound fractures of the leg were subjected to amputation, without any attempt to save the limb. What was the cause of this astonishing difference? It was clearly in some way due to the exposure of the injured parts to the external world. One obvious effect of such exposure was indicated by the odor of the discharge, which showed that the blood in the wound had undergone putrefactive change by which the bland nutrient liquid had been converted into highly irritating and poisonous substances. I have seen a man with compound fracture of the leg die within two days of the accident, as plainly poisoned by the products of putrefaction as if he had taken a fatal dose of some potent toxic drug.

An external wound of the soft parts might be healed in one of two ways. If its surfaces were clean cut, and could be brought into accurate apposition, it might unite rapidly and painlessly "by the first intention." This, however, was exceptional. Too often the surgeon's efforts to obtain primary union were frustrated, the wound inflamed and the retentive stitches had to be removed, allowing it to gape; and then, as if it had been left open from the first, healing had to be effected in the other way which it is necessary for me briefly to describe. An exposed raw surface became covered in the first instance with a layer of clotted blood or certain of its constituents, which invariably putrefied; and the irritation of the sensitive tissues by the putrid products appeared to me to account sufficiently for the inflammation which always occurred in and around an open wound during the three or four days which elapsed before what were termed "granulations" had been produced. These constituted a coarsely granular coating of very imperfect or embryonic structure, destitute of sensory nerves and prone to throw off matter or pus, rather than absorb, as freshly divided tissues do, the products of putrefaction. The granulations thus formed a beautiful living plaster, which protected the sensitive parts beneath from irritation, and the system generally from poisoning and consequent febrile disturbance. The granulations had other useful properties, of which I may mention their tendency to shrink as they grew, thus gradually reducing the dimensions of the sore. Meanwhile, another cause of its diminution was in operation. The cells of the epidermis, or scarfskin of the cutaneous margins, were perpetually producing a crop of young cells of similar nature, which gradually spread over the granulations till they covered them entirely, and a complete cicatrix or scar was the result. Such was the other mode of healing that, by granulation and cicatrization, a process which, when it proceeded unchecked to its completion, commanded our profound admiration. It was, however, essentially tedious compared with primary union, while, as we have seen, it was always preceded by more or less inflammation and fever, sometimes very serious in their effects. It was also liable to unforeseen interruptions. The sore might become larger instead of smaller, cicatrization giving place to ulceration in one of its various forms, or even to the frightful destruction of tissue which, from the circumstance that it was most frequently met with in hospitals, was termed hospital gangrene. Other serious and often fatal complications might arise, which the surgeon could only regard as untoward accidents and over which he had no efficient control.

It will be readily understood from the above description that the inflammation which so often frustrated the surgeon's endeavors after primary union was, in my opinion, essentially due to decomposition of blood within the wound.

These and many other considerations had long impressed me with the greatness of the evil of putrefaction in surgery. I had done my best to mitigate it by scrupulous ordinary cleanliness and the use of various deodorant lotions. But to prevent it altogether appeared hopeless while we believed with Liebig that its primary cause was the atmospheric oxygen which, in accordance with the researches of Graham, could not fail to be perpetually diffused through the porous dressings which were used to absorb the blood discharged from the wound. But when Pasteur had shown that putrefaction was a fermentation caused by the growth of microbes, and that these could not arise *de novo* in the decomposable substance, the problem assumed a more hopeful aspect. If the wound could be treated with some substance which, without doing too serious mischief to the human tissues, would kill the microbes already contained in it and prevent the future access of others in the living state, putrefaction might be prevented, however freely the air with its oxygen might enter. I had heard of carbolic acid as having a remarkable deodorizing effect upon sewage, and having obtained from my colleague, Dr. Anderson, professor of chemistry in the University of Glasgow, a sample which he had of this product, then little more than a chemical curiosity in Scotland, I determined to try it in compound fractures. Applying it undiluted to the wound, with an arrangement for its occasional renewal, I had the joy of seeing these formidable injuries follow the same safe and tranquil course as simple fractures, in which the skin remains unbroken.

At the same time we had the intense interest of observing in open wounds what had previously been hidden from human view—the manner in which subcutaneous injuries are repaired. Of special interest was the process by which portions of tissue killed by the violence of the accident were disposed of, as contrasted with what had till then been invariably witnessed. Dead parts had been always seen to be gradually separated from the living by an inflammatory process and thrown off as sloughs. But when protected by the antiseptic dressing from becoming putrid and therefore irritating, a structure deprived of its life caused no disturbance in its vicinity; and on the contrary, being of a nutritious nature, it served as pabulum for the growing elements of the neighboring living structures, and these became in due time entirely substituted for it. Even dead bone was seen to be thus replaced by living osseous tissue.

This suggested the idea of using threads of dead animal tissue for tying blood vessels; and this was realized by means of catgut, which is made from the intestine of the sheep. If deprived of living microbes, and otherwise properly prepared, catgut answers its purpose completely; the knot holding securely, while the ligature around the vessel becomes gradually absorbed and replaced by a ring of living tissue. The threads, instead of being left long as before, could now be cut short, and the tedious process of separation of the ligature, with its attendant serious danger of bleeding, was avoided.

Undiluted carbolic acid is a powerful caustic; and although it might be employed in compound fracture, where some loss of tissue was of little moment in comparison with the tremendous danger to be averted, it was altogether unsuitable for wounds made by the surgeon. It soon appeared, however, that the acid would answer the purpose aimed at, though used in diluted forms devoid of caustic action, and therefore applicable to operative surgery. According to our then-existing knowledge, two essential points had to be aimed at: to conduct the operation so that on its completion the wound should contain no living microbes; and to apply a dressing capable of preventing the access of other living organisms till the time should have arrived for changing it.

Carbolic acid lent itself well to both these objects. Our experience with this agent brought out what was, I believe, a new principle in pharmacology—namely, that the energy of action of any substance upon the human tissues depends not only upon the proportion in which it is contained in the material used as a vehicle for its administration, but also upon the degree of tenacity with which it is held by its solvent. Water dissolves carbolic acid sparingly and holds it extremely lightly, leaving it free to act energetically on other things for which it has greater affinity, while various organic substances absorb it greedily and hold it tenaciously. Hence its watery solution seemed admirably suited for a detergent lotion to be used during the operation for destroying any microbes that might fall upon the wound, and for purifying the surrounding skin and also the surgeon's hands and instruments. For the last-named purpose it had the further advantage that it did not act on steel.

For an external dressing the watery solution was not adapted, as it soon lost the acid it contained, and was irritating while it lasted. For this purpose some organic substances were found to answer well. Large proportions of the acid could be blended with them in so bland a form as to be unirritating; and such mixtures, while perpetually giving off enough of the volatile salt to prevent organic development in the discharges that flowed past them, served as a reliable store of the antiseptic for days together.

The appliances which I first used for carrying out the antiseptic principle were both rude and needlessly complicated. The years that have since passed have witnessed great improvements in both respects. Of the various materials which have been employed by myself and others, and their modes of application, I need say nothing except to express my belief, as a matter of long experience, that carbolic acid, by virtue of its powerful affinity for the epidermis and oily matters associated with it, and also its great penetrating power, is still the best agent at our disposal for purifying the skin around the wound. But I must say a few words regarding a most important simplification of our procedure. Pasteur, as we have seen, had shown that the air of every inhabited room teems with microbes; and for a long time I employed various more or less elaborate precautions against the living atmospheric dust, not doubting that, as all wounds except the few which healed completely by the first intention underwent putrefactive fermentation, the blood must be a peculiarly favorable soil for the growth of putrefactive microbes. But I afterwards learnt that such was by no means the case. I had performed many experiments in confirmation of Pasteur's germ theory, not indeed in order to satisfy myself of its truth, but in the hope of convincing others. I had observed that uncontaminated milk, which would remain unaltered for an indefinite time if protected from dust, was made to teem with microbes of different kinds by a very brief exposure to the atmosphere, and that the same effect was produced by the addition of a drop of ordinary water. But when I came to experiment with blood drawn with antiseptic precautions into sterilized vessels, I saw, to my surprise, that it might remain free from microbes, in spite of similar access of air or treatment with water. I even found that if very putrid blood was largely diluted with sterilized water, so as to diffuse its microbes widely and wash them of their acrid products, a drop of such dilution added to pure blood might leave it unchanged for days at the the temperature of the body, although a trace of the septic liquid undiluted caused intense putrefaction within twenty-four hours. Hence I was led to conclude that it was the grosser forms of septic mischief, rather than microbes in the attenuated condition in which they existed in the atmosphere, that we had to dread in surgical practice. And at the London Medical Congress, in 1881, I hinted, when describing the experiments I have alluded to, that it might turn out possible to disregard altogether the atmospheric dust. But greatly as I should have rejoiced at such a simplification of our procedure, if justifiable, I did not then venture to test it in practice. I knew that with the safeguards which we then employed I could ensure the safety of my patients, and I did not dare to imperil it by relaxing them. There is one golden rule for all experiments upon our fellowmen. Let the thing tried be that which, according to our best judgment, is the most likely to promote the welfare of the patient. In other words, do as you would be done by.

Nine years later, however, at the Berlin Congress in 1890, I was able to bring forward what was, I believe, absolute demonstration of the harmlessness of the atmospheric dust in surgical operations. This conclusion has been justified by subsequent experience; the irritation of the wound by antiseptic irrigation and washing may therefore now be avoided, and nature left quite undisturbed to carry out her best methods of repair, while the surgeon may conduct his operations as simply as in former days, provided always that, deeply impressed with the tremendous importance of his object, and inspiring the same conviction in all his assistants, he vigilantly maintains from first to last, with care that, once learnt, becomes instinctive, but for the want of which nothing else can compensate, the use of the simple means which will suffice to exclude from the wound the coarser forms of septic impurity.

Even our earlier and ruder methods of carrying out the antiseptic principle soon produced a wonderful change in my surgical wards in the Glasgow Royal Infirmary, which, from being some of the most unhealthy in the kingdom, became, as I believe I may say without exaggeration, the healthiest in the world; while other wards, separated from mine only by a passage a few feet broad, where former modes of treatment were for a while continued, retained their former insalubrity. This result, I need hardly remark, was not in any degree due to special skill on my part, but simply to the strenuous endeavor to carry out strictly what seemed to me a principle of supreme importance.

Equally striking changes were afterwards witnessed in other institutions. Of these, I may give one example. In the great Allgemeines Krankenhaus, of Munich, hospital gangrene had become more and more rife from year to year, till at length the frightful condition was reached that 80 per cent. of all wounds became affected by it. It is only just to the memory of Professor von Nussbaum, then the head of that establishment, to say that he had done his utmost to check this frightful scourge; and that the evil was not caused by anything peculiar in his management was shown by the fact that in a private hospital under his care there was no unusual unhealthiness. The larger institution seemed to have become hopelessly infected, and the city authorities were contemplating its demolition and reconstruction. Under these circumstances, Professor von Nussbaum dispatched his chief assistant, Dr. Lindpaintner, to Edinburgh, where I at that time occupied the chair of clinical surgery, to learn the details of the antiseptic system as we then practiced it. He remained until he had entirely mastered them, and after his return all the cases were on a certain day dressed on our plan. From that day forward not a single case of hospital gangrene occurred in the Krankenhaus. The fearful disease pyæma likewise disappeared, and erysipelas soon followed its example.

But it was by no means only in removing the unhealthiness of hospitals that the antiseptic system showed its benefits. Inflammation being suppressed, with attendant pain, fever and wasting discharge, the sufferings of the patient were, of course, immensely lessened; rapid primary union being now the rule, convalescence was correspondingly curtailed; while, as regards safety and the essential nature of the mode of repair, it became a matter of indifference whether the wound had clean-cut surfaces which could be closely approximated, or whether the injury inflicted had been such as to cause destruction of tissue. And operations which had been regarded from time immemorial as unjustifiable were adopted with complete safety.

It pleases me to think that there is an ever-increasing number of practitioners throughout the world to whom this will not appear the language of exaggeration. There are cases in which, from the situation of the part concerned or other unusual circumstances, it is impossible to carry out the antiseptic system completely. These, however, are quite exceptional; and even in them much has been done to mitigate the evil which can not be altogether avoided.

I ask your indulgence if I have seemed to dwell too long upon matters in which I have been personally concerned. I now gladly return to the labors of others.

The striking results of the application of the germ theory to surgery acted as a powerful stimulus to the investigation of the nature of the micro-organisms concerned; and it soon appeared that putrefaction was by no means the only evil of microbic origin to which wounds were liable. I had myself very early noticed that hospital gangrene was not necessarily attended by any unpleasant odor; and I afterwards made a similar observation regarding the matter formed in a remarkable epidemic of erysipelas in Edinburgh obviously of infective character. I had also seen a careless dressing followed by the occurrence of suppuration without putrefaction. And as these non-putrefactive disorders had the same self-propagating property as ferments, and were suppressed by the same antiseptic agencies which were used for combating the putrefactive microbes, I did not doubt that they were of an analogous origin; and I ventured to express the view that, just as the various fermentations had each its special microbe, so it might be with the various complications of wounds. This surmise was afterwards amply verified. Professor Ogston, of Aberdeen, was an early worker in this field, and showed that in acute abscesses, that is to say, those which run a rapid course, the matter, although often quite free from unpleasant odor, invariably contains micro-organisms belonging to the group which, from the spherical form of their elements, are termed micrococci; and these he classed as streptococci or staphylococci, according as they were arranged in chains or disposed in irregular clusters like bunches of grapes. The German pathologist, Fehleisen, followed with a beautiful research, by which he clearly proved that erysipelas is caused by a streptococcus. A host of earnest workers in different countries have cultivated the new science of bacteriology, and, while opening up a wide fresh domain of biology, have demonstrated in so many cases the causal relation between special micro-organisms and special diseases, not only in wounds, but in the system generally, as to afford ample confirmation of the induction which had been made by Pasteur that all infective disorders are of microbic origin.

Not that we can look forward with anything like confidence to being able to see the *materies morbi* of every disease of this nature. One of the latest of such discoveries has been that by Pfeiffer, of Berlin, of the bacillus of influenza, perhaps the most minute of all micro-organisms ever yet detected. The bacillus of anthrax, the cause of a plague common among cattle in some parts of Europe, and often communicated to sorters of foreign wool in this country, is a giant as compared with this tiny being; and supposing the microbe of any infectious fever to be as much smaller than the influenza bacillus as this is less than that of anthrax, a by no means unlikely hypothesis, it is probable that it would never be visible to man. The improvements of the microscope, based on the principle established by my father in the earlier part of the century, have apparently nearly reached the limits of what is possible. But that such parasites are really the causes of all this great class of diseases can no longer be doubted.

The first rational step towards the prevention or cure of disease is to know its cause; and it is impossible to over-estimate the practical value of researches, such as those to which I am now referring. Among their many achievements is what may be fairly regarded as the most important discovery ever made in pathology, because it revealed the true nature of the disease which causes more sickness and death in the human race than any other. It was made by Robert Koch, who greatly distinguished himself, when a practitioner in an obscure town in Germany, by the remarkable combination of experimental acuteness and skill, chemical and optical knowledge and successful micro-photography which he brought to bear upon the illustration of infective diseases of wounds in the lower animals; in recognition of which service the enlightened Prussian Government at once appointed him to an official position of great importance in Berlin. There he conducted various important researches; and at the London Congress, in 1881, he showed to us, for the first time, the bacillus of tubercle. Wonderful light was thrown, by this discovery, upon a great group of diseases which had before been rather guessed than known to be of an allied nature; a precision and efficacy never before possible was introduced into their surgical treatment, while the physician became guided by new and sure light as regards their diagnosis and prevention.

At that same London Congress Koch demonstrated to us his "plate culture" of bacteria, which was so important that I must devote a few words to its description. With a view to the successful study of the habits and effects of any particular microbe outside the living body it is essential that it should be present unmixed in the medium in which it is cultivated. It can be readily understood how difficult it must have been to isolate any particular micro-organism when it existed mixed, as was often the case, with a multitude of other forms. In fact, the various ingenious attempts made to effect this object had often proved entire failures. Koch, however, by an ingenious procedure converted what had been before impossible into a matter of the utmost facility. In the broth or other nutrient liquid which was to serve as food for the growing microbe he dissolved, by aid of heat, just enough gelatine to ensure that, while it should become a solid mass when cold, it should remain fluid, though reduced in temperature so much as to be incapable of killing living germs. To the medium thus partially cooled was added some liquid containing, among others, the microbe to be investigated; and the mixture was thoroughly shaken so as to diffuse the bacteria and separate them from each other. Some of the liquid was then poured out in a thin layer upon a glass plate and allowed to cool so as to assume the solid form. The various microbes, fixed in the gelatine and so prevented from intermingling, proceeded to develop each its special progeny, which in course of time showed itself as an opaque speck in the transparent film. Any one of such specks could now be removed and transferred to another vessel in which the microbe composing it grew in perfect isolation.

Pasteur was present at this demonstration, and expressed his sense of the great progress effected by the new method. It was soon introduced into his own institute and other laboratories throughout the world; and it has immensely facilitated bacteriological study.

One fruit of it in Koch's own hands was the discovery of the microbe of cholera in India, whither he went to study the disease. This organism was termed by Koch from its curved form the "comma bacillus," and by the French the cholera vibrio. Great doubts were for a long time felt regarding this discovery. Several other kinds of bacteria were found of the same shape, some of them producing very similar appearances in culture media. But bacteriologists are now universally agreed that, although various other conditions are necessary to the production of an attack of cholera besides the mere presence of the vibrio, yet it is the essential *materies morbi;* and it is by the aid of the diagnosis which its presence in any case of true cholera enables the bacteriologist to make, that threatened invasions of this awful disease have of late years been so successfully repelled from our shores. If bacteriology had done nothing more for us than this it might well have earned our gratitude.

I have next to invite your attention to some earlier work of Pasteur. There is a disease known in France under the name of *choléra des poules,* which often produced great havoc among the poultry yards of Paris. It had been observed that the blood of birds that had died of this disease was peopled by a multitude of minute bacteria, not very dissimilar in form and size to the microbe of the lactic ferment to which I have before referred. And Pasteur found that, if this bacterium was cultivated outside the body for a protracted period under certain conditions, it underwent a remarkable diminution of its virulence; so that, if inoculated into a healthy fowl, it no longer caused the death of the bird, as it would have done in its original condition, but produced a milder form of the disease which was not fatal. And this altered character of the microbe, caused by certain conditions, was found to persist in successive generations cultivated in the ordinary way. Thus was discovered the great fact, of what Pasteur termed *atténuation du virus,* which at once gave the clue to understanding what had before been quite mysterious, the difference in virulence of the same disease in different epidemics.

But he made the further very important observation that a bird which had gone through the mild form of the complaint had acquired immunity against it in its most virulent condition. Pasteur afterwards succeeded in obtaining mitigated varieties of microbes for some other diseases; and he applied with great success the principle which he had discovered in fowl-cholera for protecting the larger domestic animals against the plague of anthrax. The preparations used for such preventive inoculations he termed "vaccins" in honor of our great countryman, Edward Jenner. For Pasteur at once saw the analogy between the immunity to fowl-cholera produced by its attenuated virus and the protection afforded against smallpox by vaccination. And while pathologists still hesitated, he had no doubt of the correctness of Jenner's expression *variolæ vaccinæ,* or smallpox in the cow.

It is just a hundred years since Jenner made the crucial experiment of inoculating with smallpox a boy whom he had previously vaccinated, the result being, as he anticipated, that the boy was quite unaffected. It may be remarked that this was a perfectly legitimate experiment, involving no danger to the subject of it. Inoculation was at that time the established practice; and if vaccination should prove nugatory, the inoculation would be only what would have been otherwise called for; while it would be perfectly harmless if the hoped-for effect of vaccination had been produced.

We are a practical people, not much addicted to personal commemorations; although our nation did indeed celebrate, with fitting splendor, the jubilee of the reign of our beloved queen; and, at the invitation of Glasgow, the scientific world has lately marked, in a manner, though different, as imposing, the jubilee of the life-work of a sovereign in science (Lord Kelvin). But while we can not be astonished that the centenary of Jenner's immortal discovery should have failed to receive general recognition in this country, it is melancholy to think that this year should, in his native country, have been distinguished by a terrible illustration of the results which would sooner or later inevitably follow the general neglect of his prescriptions.

I have no desire to speak severely of the Gloucester Guardians. They are not sanitary authorities, and had not the technical knowledge necessary to enable them to judge between the teachings of true science and the declamations of misguided, though well-meaning, enthusiasts. They did what they believed to be right; and when roused to a sense of the greatness of their mistake, they did their very best to repair it, so that their city is said to be now the best vaccinated in Her Majesty's dominions. But though by their praiseworthy exertions they succeeded in promptly checking the raging epidemic, they can not recall the dead to life, or restore beauty to marred features, or sight to blinded eyes. Would that the entire country and our legislature might take duly to heart this object lesson!

How completely the medical profession were convinced of the efficacy of vaccination in the early part of this century was strikingly illustrated by an account given by Professor Crookshank, in his interesting history of this subject, of several eminent medical men in Edinburgh meeting to see the to them unprecedented fact of a vaccinated person having taken smallpox. It has, of course, since become well known that the milder form of the disease, as modified by passing through the cow, confers a less permanent protection than the original human disorder. This it was, of course, impossible for Jenner to foresee. It is, indeed, a question of degree, since a second attack of ordinary smallpox is occasionally known to occur, and vaccination, long after it has ceased to give perfect immunity, greatly modifies the character of the disorder and diminishes its danger. And happily, in revaccination after a certain number of years we have the means of making Jenner's work complete. I understand the majority of the commissioners, who have recently issued their report upon this subject, while recognizing the value of importance of revaccination, are so impressed with the difficulties that would attend making it compulsory by legislation that they do not recommend that course; although it is advocated by two of their number who are of peculiarly high authority on such a question. I was lately told by a Berlin professor that no serious difficulty is experienced in carrying out the compulsory law that prevails in Germany. The masters of the schools are directed to ascertain in the case of every child attaining the age of twelve whether revaccination has been practiced. If not, and the parents refuse to have it done, they are fined one mark. If this does not prove effectual, the fine is doubled; and if even the double penalty should not prove efficacious, a second doubling of it would follow, but, as my informant remarked, it is very seldom that it is called for. The result is that smallpox is a matter of extreme rarity in that country; while it is absolutely unknown in the huge German army, in consequence of the rule that every soldier is revaccinated on entering the service. Whatever view our legislature may take on this question, one thing seems to me clear: that it will be the duty of government to encourage by every available means the use of calf lymph, so as to exclude the possibility of the communication of any human disease to the child, and to institute such efficient inspection of vaccination institutes as shall ensure careful antiseptic arrangements, and so prevent contamination by extraneous microbes. If this were done, "conscientious objections" would cease to have any rational basis. At the same time, the administration of the regulations on vaccination should be transferred (as advised by the commissioners) to competent sanitary authorities.

But to return to Pasteur. In 1880 he entered upon the study of that terrible but then most obscure disease, hydrophobia, or rabies, which from its infective character he was sure must be of microbic origin, although no microorganism could be detected in it. He early demonstrated the new pathological fact that the virus had its essential seat in the nervous system. This proved the key to his success in this subject. One result that flowed from it has been the cause of unspeakable consolation to many. The foolish practice is still too prevalent of killing the dog that has bitten any one, on the absurd notion that, if it were mad, its destruction would prevent the occurrence of hydrophobia in the person bitten. The idea of the bare possibility of the animal having been so affected causes an agony of suspense during the long weeks or months of possible incubation of the disease. Very serious nervous symptoms aping true hydrophobia have been known to result from the terror thus inspired. Pasteur showed that if a little of the brain or spinal cord of a dog that had been really mad was inoculated in an appropriate manner into a rabbit, it infallibly caused rabies in that animal in a few days. If, therefore, such an experiment was made with a negative result, the conclusion might be drawn with certainty that the dog had been healthy. It is perhaps right that I should say that the inoculation is painlessly done under an anesthetic, and that in the rabbit rabies does not assume the violent form that it does in the dog, but produces gradual loss of power, with little, if any, suffering.

This is the more satisfactory because rabbits in which the disease has been thus artificially induced are employed in carrying out what was Pasteur's greatest triumph, the preventive treatment of hydrophobia in the human subject. We have seen that Pasteur discovered that microbes might under some circumstances undergo mitigation of their virulence. He afterwards found that under different conditions they might have it exalted, or, as he expressed it, there might be a *renforcement du virus*. Such proved to be the case with rabies in the rabbit; so that the spinal cords of animals which had died of it contained the poison in a highly intensified condition. But he also found that if such a highly virulent cord was suspended under strict antiseptic precautions in a dry atmosphere at a certain temperature, it gradually from day to day lost its potency, till in course of time it became absolutely inert. If now an emulsion of such a harmless cord was introduced under the skin of an animal, as in the subcutaneous administration of morphia, it might be followed without harm another day by a similar dose of a cord still rather poisonous; and so from day to day stronger and stronger ejections might be used, the system becoming gradually accustomed to the poison, till a degree of virulence had been reached far exceeding that of the bite of a mad dog. When this had been attained, the animal proved incapable of taking the disease in the ordinary way; and more than that, if such treatment was adopted after an animal had already received the poison, provided that too long a time had not elapsed, the outbreak of the disease was prevented. It was only after great searching of heart that Pasteur, after consultation with some trusted medical friends, ventured upon trying this practice upon man. It has since been extensively adopted in various parts of the world with increasing success as the details of the method were improved. It is not, of course, the case that every one bitten by a really rabid animal takes the disease; but the percentage of those who do so, which was formerly large, has been reduced almost to zero by this treatment, if not too long delayed.

While the intensity of rabies in the rabbit is undoubtedly due to a peculiarly virulent form of the microbe concerned, we can not suppose that the daily diminishing potency of the cord suspended in dry warm air is an instance of attenuation of virus, using the term "virus" as synonymous with the microbe concerned. In other words, we have no reason to believe that the special microorganism of hydrophobia continues to develop in the dead cord and produce successively a milder and milder progeny, since rabies can not be cultivated in the nervous system of a dead animal. We must rather conclude that there must be some chemical poison present which gradually loses its potency as time passes. And this leads me to refer to another most important branch of this large subject of bacteriology, that of the poisonous products of microbes.

It was shown several years ago by Roux and Yersin, working in the Institut Pasteur, that the crust or false membrane which forms upon the throats of patients affected with diphtheria contains bacteria which can be cultivated outside the body in a nutrient liquid, with the result that it acquires poisonous qualities of astonishing intensity, comparable to that of the secretion of the poison glands of the most venomous serpents. And they also ascertained that the liquid retained this property after the microbes had been removed from it by filtration, which proved that the poison must be a chemical substance in solution, as distinguished from the living element which had produced it. These poisonous products of bacteria, or toxins, as they have been termed, explain the deadly effects of some microbes, which it would otherwise be impossible to understand. Thus, in diphtheria itself, the special bacillus which was shown by Löffler to be its cause does not become propagated in the blood, like the microbe of chicken cholera, but remains confined to the surface on which it first appeared; but the toxin which it secretes is absorbed from that surface into the blood, and so poisons the system. Similar observations have been made with regard to the microbes of some other diseases, as, for example, the bacillus of tetanus or lockjaw. This remains localized in the wound, but forms a special toxin of extreme potency, which becomes absorbed and diffused through the body.

Wonderful as it seems, each poisonous microbe appears to form its own peculiar toxin. Koch's tuberculin was of this nature, a product of the growth of the tubercle bacillus in culture media. Here, again, great effects were produced by extremely minute quantities of the substance, but here a new peculiarity showed itself, *viz.*, that patients affected with tubercular disease, in any of its varied forms, exhibited inflammation in the affected part and general fever after receiving under the skin an amount of the material which had no effect whatever upon healthy persons. I witnessed, in Berlin, some instances of these effects, which were simply astounding. Patients affected with a peculiar form of obstinate ulcer of the face showed, after a single injection of the tuberculin, violent inflammatory redness and swelling of the sore and surrounding skin; and, what was equally surprising, when this disturbance subsided the disease was found to have undergone great improvement. By repetitions of such procedures, ulcers which had previously been steadily advancing, in spite of ordinary treatment, became greatly reduced in size, and in some instances apparently cured. Such results led Koch to believe that he had obtained an effectual means of dealing with tubercular disease in all its forms. Unhappily, the apparent cure proved to be only of transient duration, and the high hopes which had been inspired by Koch's great reputation were dashed. It is but fair to say that he was strongly urged to publish before he was himself disposed to do so, and we can not but regret that he yielded to the pressure put upon him.

But though Koch's sanguine anticipations were not realized, it would be a great mistake to suppose that his labors with tuberculin have been fruitless. Cattle are liable to tubercle, and, when affected with it, may become a very serious source of infection for human beings, more especially when the disease affects the udders of cows, and so contaminates the milk. By virtue of the close affinity that prevails between the lower animals and ourselves, in disease as well as in health, tuberculin produces fever in tubercular cows in doses which do not affect healthy beasts. Thus, by the subcutaneous use of a little of the fluid, tubercle latent in internal organs of an apparently healthy cow can be with certainty revealed, and the slaughter of the animal after this discovery protects man from infection.

It has been ascertained that glanders presents a precise analogy with tubercle as regards the effects of its toxic products. If the microbe which has been found to be the cause of this disease is cultivated in appropriate media it produces a poison which has received the name of mallein, and the subcutaneous injection of a suitable dose of this fluid into a glandered horse causes striking febrile symptoms which do not occur in a healthy animal. Glanders, like tubercle, may exist in insidious latent forms which there was formerly no means of detecting, but which are at once disclosed by this means. If a glandered horse has been accidentally introduced into a large stable this method of diagnosis surely tells if it has infected others. All receive a little mallein. Those which become affected with fever are slaughtered, and thus not only is the disease prevented from spreading to other horses, but the grooms are protected from a mortal disorder.

This valuable resource sprang from Koch's work on tuberculin, which has also indirectly done good in other ways. His distinguished pupil, Behring, has expressly attributed to those researches the inspiration of the work which led him and his famous collaborator, the Japanese Kitasato, to their surprising discovery of antitoxic serum. They found that if an animal of a species liable to diphtheria or tetanus received a quantity of the respective toxin, so small as to be harmless, and afterwards, at suitable intervals, successively stronger and stronger doses, the creature, in course of time, acquired such a tolerance for the poison as to be able to receive with impunity a quantity very much greater than would at the outset have proved fatal. So far we have nothing more than seems to correspond with the effects of the increasingly potent cords in Pasteur's treatment of rabies. But what was entirely new in their results was that, if blood was drawn from an animal which had acquired this high degree of artificial immunity, and some of the clear fluid or serum which exuded from it after it had clotted was introduced under the skin of another animal, this second animal acquired a strong, though more transient, immunity against the particular toxin concerned. The serum in some way counteracted the toxin or was antitoxic. But, more than that, if some of the antitoxic serum was applied to an animal after it had already received a poisonous dose of the toxin it preserved the life of the creature, provided that too long a time had not elapsed after the poison was introduced. In other words, the antitoxin proved to be not only preventive but curative.

Similar results were afterwards obtained by Ehrlich, of Berlin, with some poisons not of bacterial origin, but derived from the vegetable kingdom; and quite recently the independent labors of Calmette, of Lille, and Fraser, of Edinburgh, have shown that antidotes of wonderful efficacy against the venom of serpents may be procured on the same principle. Calmette has obtained antitoxin so powerful that a quantity of it only a 200,000th part of the weight of an animal will protect it perfectly against a dose of the secretion of the poison glands of the most venomous serpents known to exist, which, without such protection, would have proved fatal in four hours. For curative purposes larger quantities of the remedy are required, but cases have been already published by Calmette in which death appears to have been averted in the human subject by this treatment.

Behring's darling object was to discover means of curing tetanus and diphtheria in man. In tetanus the conditions are not favorable; because the specific bacilli lurk in the depths of the wound, and only declare their presence by symptoms caused by their toxin having been already in a greater or less amount diffused through the system; and in every case of this disease there must be a fear that the antidote may be applied too late to be useful. But in diphtheria the bacilli very early manifest their presence by the false membrane which they cause upon the throat, so that the antitoxin has a fair chance; and here we are justified in saying that Behring's object has been attained.

The problem, however, was by no means so simple as in the case of some mere chemical poison. However effectual the antitoxin might be against the toxin, if it left the bacilli intact, not only would repeated injections be required to maintain the transient immunity to the poison perpetually secreted by the microbes, but the bacilli might, by their growth and extension, cause obstruction of the respiratory passages.

Roux, however, whose name must always be mentioned with honor in relation to this subject, effectually disposed of this difficulty. He showed by experiments on animals that a diphtheritic false membrane, rapidly extending and accompanied by surrounding inflammation, was brought to a stand by the use of the antitoxin, and soon dropped off, leaving a healthy surface. Whatever be the explanation, the fact was thus established that the antitoxic serum, while it renders the toxin harmless, causes the microbe to languish and disappear.

No theoretical objection could now be urged against the treatment; and it has during the last two years been extensively tested in practice in various parts of the world, and it has gradually made its way more and more into the confidence of the profession. One important piece of evidence in its favor in this country is derived from the report of the six large hospitals under the management of the London Asylums Board. The medical officers of these hospitals at first naturally regarded the practice with scepticism, but as it appeared to be at least harmless they gave it a trial; and during the year 1895 it was very generally employed upon the 2,182 cases admitted, and they have all become convinced of its great value. In the nature of things, if the theory of the treatment is correct, the best results must be obtained when the patients are admitted at an early stage of the attack, before there has been time for much poisoning of the system, and accordingly we learn from the report that, comparing 1895 with 1894, during which latter year the ordinary treatment had been used, the percentage of mortality, in all the six hospitals combined, among the patients admitted on the first day of the disease, which in 1894 was 22.5, was only 4.6 in 1895; while for those admitted on the second day the numbers are 27 for 1894 and 14.8 for 1895. Thus for cases admitted on the first day the mortality was only one fifth of what it was in the previous year, and for those entering on the second it was halved. Unfortunately, in the low parts of London, which furnish most of these patients, the parents too often delay sending in the children till much later, so that on the average no less than 67.5 per cent. were admitted on the fourth day of the disease or later. Hence the aggregate statistics of all cases are not nearly so striking. Nevertheless, taking it altogether, the mortality in 1895 was less than had ever before been experienced in those hospitals. I should add that there was no reason to think that the disease was of a milder type than usual in 1895; and no change whatever was made in the treatment except as regards the antitoxic injections.

There is one piece of evidence recorded in the report which, though it is not concerned with high numbers, is well worthy of notice. It relates to a special institution to which convalescents from scarlet fever are sent from all the six hospitals. Such patients occasionally contract diphtheria, and when they do so the added disease has generally proved extremely fatal. In the five years preceding the introduction of the treatment with antitoxin the mortality from this cause had never been less than 50 per cent., and averaged on the whole 61.9 per cent. During 1895, under antitoxin, the deaths among the 119 patients of this class were only 7.5 per cent., or one eighth of what had been previously experienced. This very striking result seems to be naturally explained by the fact that these patients being already in hospital when the diphtheria appeared, an unusually early opportunity was afforded for dealing with it.

There are certain cases of so malignant a character from the first that no treatment will probably ever be able to cope with them. But taking all cases together, it seems probable that Behring's hope that the mortality may be reduced to five per cent. will be fully realized when the public become alive to the paramount importance of having the treatment commenced at the outset of the disease.

There are many able workers in the field of bacteriology whose names time does not permit me to mention, and to whose important labors I can not refer; and even those researches of which I have spoken have been, of course, most inadequately dealt with. I feel this especially with regard to Pasteur, whose work shines out more brightly the more his writings are perused.

I have lastly to bring before you a subject which, although not bacteriological, has intimate relations with bacteria. If a drop of blood is drawn from the finger by a prick with a needle and examined microscopically between two plates of glass, there are seen in it minute solid elements of two kinds, the one pale orange bi-concave discs, which, seen in mass, give the red color to the vital fluid, the other more or less granular spherical masses of the soft material called protoplasm, destitute of color, and therefore called the colorless or white corpuscles. It has been long known that if the microscope was placed at such a distance from a fire as to have the temperature of the human body, the white corpuscles might be seen to put out and retract little processes or pseudopodia, and by their means crawl over the surface of the glass, just like the extremely low forms of animal life termed, from this faculty of changing their form, amœbæ. It was a somewhat weird spectacle, that of seeing what had just before been constituents of our own blood moving about like independent creatures. Yet there was nothing in this inconsistent with what we knew of the fixed components of the animal frame. For example, the surface of a frog's tongue is covered with a layer of cells, each of which is provided with two or more lashing filaments or cilia, and those of all the cells acting in concert cause a constant flow of liquid in a definite direction over the organ. If we gently scrape the surface of the animal's tongue we can detach some of these ciliated cells; and on examining them with the microscope in a drop of water we find that they will continue for an indefinite time their lashing movements, which are just as much living or vital in their character as the writhings of a worm. And, as I observed many years ago, these detached cells behave under the influence of a stimulus just like parts connected with the body, the movements of the cilia being excited to greater activity by gentle stimulation, and thrown into a state of temporary inactivity when the irritation was more severe. Thus each constituent element of our bodies may be regarded as in one sense an independent living being, though all work together in marvelous harmony for the good of the body politic. The independent movements of the white corpuscles outside the body were therefore not astonishing; but they long remained matters of mere curiosity. Much interest was called to them by the observation of the German pathologist Cohnheim that in some inflammatory conditions they passed through the pores in the walls of the finest blood vessels, and thus escaped into the interstices of the surrounding tissues. Cohnheim attributed their transit to the pressure of the blood. But why it was that, though larger than the red corpuscles, and containing a nucleus which the red ones have not, they alone passed through the pores of the vessels, or why it was that this emigration of the white corpuscles occurred abundantly in some inflammations and was absent in others, was quite unexplained.

These white corpuscles, however, have been invested with extraordinary new interest by the researches of the Russian naturalist and pathologist Metchnikoff. He observed that, after passing through the walls of the vessels, they not only crawl about like amœbæ, but, like them, receive nutritious materials into their soft bodies and digest them. It is thus that the effete materials of a tadpole's tail are got rid of; so that they play a most important part in the function of absorption.

But still more interesting observations followed. He found that a microscopic crustacean, a kind of water-flea, was liable to be infested by a fungus which had exceedingly sharp-pointed spores. These were apt to penetrate the coats of the creature's intestine, and project into its body cavity. No sooner did this occur with any spore than it became surrounded by a group of the cells which are contained in the cavity of the body and correspond to the white corpuscles of our blood. These proceeded to attempt to devour the spore, and if they succeeded in every such case the animal was saved from the invasion of the parasite. But if the spores were more than could be disposed of by the devouring cells (phagocytes, as Metchnikoff termed them) the water-flea succumbed.

Starting from this fundamental observation, he ascertained that the microbes of infective diseases are subject to this same process of devouring and digestion, carried on both by the white corpuscles and by cells that line the blood-vessels. And by a long series of most beautiful researches he has, as it appears to me, firmly established the great truth that phagocytosis is the main defensive means possessed by the living body against the invasion of its microscopic foes. The power of the system to produce antitoxic substances to counteract the poisons of microbes is undoubtedly in its own place of great importance. But in the large class of cases in which animals are naturally refractory to particular infective diseases the blood is not found to yield any antitoxic element by which the natural immunity can be accounted for. Here phagocytosis seems to be the sole defensive agency. And even in cases in which the serum does possess antitoxic, or, as it would seem in some cases, germicidal properties, the bodies of the dead microbes must at last be got rid of by phagocytosis, and some recent observations would seem to indicate that the useful elements of the serum may be, in part at least, derived from the digestive juices of the phagocytes. If ever there was a romantic chapter in pathology, it has surely been that of the story of phagocytosis.

I was myself peculiarly interested by these observations of Metchnikoff's, because they seemed to me to afford clear explanation of the healing of wounds by first intention under circumstances before incomprehensible. This primary union was sometimes seen to take place in wounds treated with water-dressing, that is to say, a piece of wet lint covered with a layer of oiled silk to keep it moist. This, though cleanly when applied, was invariably putrid within twenty-four hours. The layer of blood between the cut surfaces was thus exposed at the outlet of the wound to a most potent septic focus. How was it prevented from putrefying, as it would have done under such influence if, instead of being between divided living tissues, it had been between plates of glass or other indifferent material? Pasteur's observations pushed the question a step further. It now was, How were the bacteria of putrefaction kept from propagating in the decomposable film? Metchnikoff's phagocytosis supplied the answer. The blood between the lips of the wound became rapidly peopled with phagocytes, which kept guard against the putrefactive microbes and seized them as they endeavored to enter.

If phagocytosis was ever able to cope with septic microbes in so concentrated and intense a form, it could hardly fail to deal effectually with them in the very mitigated condition in which they are present in the air. We are thus strongly confirmed in our conclusion that the atmospheric dust may safely be disregarded in our operations, and Metchnikoff's researches, while they have illumined the whole pathology of infective diseases, have beautifully completed the theory of antiseptic treatment in surgery.

I might have taken equally striking illustrations of my theme from other departments in which microbes play no part. In fact any attempt to speak of all that the art of healing has borrowed from science and contributed to it during the past half century would involve a very extensive dissertation on pathology and therapeutics. I have culled specimens from a wide field; and I only hope that in bringing them before you I have not overstepped the bounds of what is fitting before a mixed company. For many of you my remarks can have had little if any novelty; for others they may perhaps possess some interest as showing that medicine is no unworthy ally of the British Association; that, while her practice is ever more and more based on science, the ceaseless efforts of her votaries to improve what have been fittingly designated *Quæ prosunt omnibus artes* are ever adding largely to the sum of abstract knowledge.

PROGRESS AND THE SCIENCES

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THE Stone Age; the Bronze Age; the Iron Age; and this? The Age of Science; and it is little wonder that many have so characterized it. We hear of research being carried on in all the great industries, of vast sums being raised for research and of achievements made possible only by the aid of science. One sometimes wonders whether we are passing blindly through this age of science as did, we may think, the dwellers of the earlier eras. Or is the present period more purposeful? Has science itself an aim and if so are we, at present, sufficiently scientifically minded to relate the scientific aim to the age and cause a purposeful development?

No one can truly answer these questions in all their significance and doubtlessly each who tried would have a different answer. One has but to read such essays as "Daedalus," by Haldane, and "Icarus," by Russell, to see how differently science with respect to the future may be looked upon; or to witness such a drama as "R. U. R." to have material and mechanical progress appear in a somewhat different light from that in which we usually view it. It is well, perhaps, in view of all the appeals for financial aid, the endowed research institutes and the publicly supported government laboratories, that those who have tried to look at the matter broadly should attempt, from time to time, to draw the thing as they see it.

Surely there can be no question but what science has given us a multitude of mechanical devices, but if we consider the complexity these have added to life we may well wonder whether they have contributed one drop of true and lasting happiness to our brimming cup. Moreover, those whom we think of as scientists are, in general, not concerned with these applications when toiling in their remote laboratories. When the expansion of steam under pressure was first studied, the worker little dreamed of the transcontinental railways which would soon spread like a net-work over all countries. And when Faraday first passed a wire over a magnet the unending possibilities of the electrical dynamo were not his aim. The names which appear above the articles in our scientific journals to-day are not, for the most part, those of men who are in any way relating science to the everyday life of man. The authors are more interested in the broad generalizations of pure science and are inclined to scoff at applied science. Yet with delightful inconsistency they will rise with one accord if asked why they are pursuing science, and say that without the advancement of pure science in this generation man's material progress in the next will be halted. How good they are to work without personal reward that their children's children may have bread enough and to spare—and unending mechanical devices to add to the complexity of life! Few would admit that science is a high-class sport enjoyed by certain high-class minds. They must rather hallow their labors before the imaginary shrine of nations yet unborn rising to sing their praise. It would be cruel to puncture their holiness with such words as ambition, self-esteem, self-aggrandizement or some of the psychological terms of motivation such as compensation, will-to-power, Jehovah complex.

Artists and writers have beheld the works of their hands and said, "It is good." It is said that when Händel completed the Hallelujah Chorus he was so overwhelmed with the beauty of his creation that he imagined he saw the heavens open before him and angels ascending and descending. Thackeray often interrupted his work on "Vanity Fair" to march up and down the room exclaiming, "That's genius." Ah, but the scientist is of different clay! He will rarely admit any such joys in his labors.

Some one has spoken of the scientists as the "saints of the twentieth century." The majority, in this money-mad day, would prefer, looking at his baggy knees and empty purse, to call the scientist a fool. To himself he may often admit the latter, but to the world he coyly implies the former. Doubtlessly the truth is that he is just the proper mixture of saint and fool to make him completely human and just what he is—not to be praised for his high-sounding altruism for the future nor yet to be pitied for the pleasant hardships he causes himself and those dependent upon him. Perhaps the scientists, the artists, the writers—all of us—are mere pawns upon this checkerboard of nights and days, one sent hither by his particular glandular balance, another thither by his ancestry or his reactions to environment.

But whether the scientist is sincere and purposeful in his work or not, there can be no doubt of his results. All our "modern conveniences" are the result of scientific inquiry and application—some few work out in the laboratories of the companies selling the products at a few hundred per centum profit, the majority developed on the heritage of the past, built up by those interested in pure science. Nowhere is it truer than in science that one generation shall labor and another shall enter into the fruits of its labors. In the middle eighties of the last century, a chemist prepared dichloroethylsulfide. In 1918 every one called it by a simpler name—"mustard gas." What an unfortunate example! And yet how few are the examples of the achievements of science which are wholly without unfortunate aspects if we look at the full possibilities. The industry which grasps the nitrogen from the air and with its fertilizers multiplies the yield of our vast acreage may to-morrow send forth the munitions which will strew those same fields with human wreckage. The radio may fill the nights with music or it may turn back the pages of science and teach the multitudes that the earth is flat. The telegraph may one day spread joy with the news that the income tax has been reduced half of one per centum, and next day sorrow at the news that families will be split asunder in each petty nation in order that their individual coinage may be made safe for their monied classes. The same reproducing device which may lift our souls to the heights of a grand symphony may also cause us to respond once more to the pulse of primitive strains. The food which science has given us is better and more varied than that of kings of yester-year, but this very blessing has given us many a sleepless night, and 'twould be a happy bargain if we could trade our teeth for theirs. The automobile may be a pleasure and a business necessity, but little permanent value can it offer to the group or the individual if its acquirement by easy payment plans obligates the future to decreasing currency values and forced increased production. The mortgaging of homes to satisfy the cravings of a world on pleasure bent may reduce us to a new form of wandering tribes, the very wealthy migrating from one palatial residence to another, the poor journeying in worn-out vehicles from one place of short employment to another. The morning paper gives us news from all corners of the earth of war, pestilence and famine; the murders, suicides and robberies; the sorrows and intrigues of the world are laid before us at breakfast and the evening paper adds the daring daylight hold-ups. And so on, examples showing the pleasant results and likewise the equally unpleasant consequences and dangers of applied science could be added without end.

But if this is all, the shortening of time and space, a few new toys of questionable merit—a little louder but as empty quite—is not the clown, the actor, the artist, he who carries us away with his songs, he who gives us a brief flight from reality by the joys and sorrows of his imaginary characters, are not these to be more blessed than the scientist? For each in his own way permits us for a moment to forget the cares that infest the day.

Before we consider these questions further, we may look upon science as doing other things. Not only is it building from the gifts of nature, but it is constantly carrying on a battle with nature. We tower into the sky our great cathedrals of commerce, and before the last stone is in place nature urges the brick and steel and mortar to crumble. We span the broad rivers in order that they shall no longer be barriers to our speed, but e'er the last cable is spun wind and weather have started the work which, were it not for man's constant vigilance, would one day carry the mighty structure down stream. We modify plants and animals for our use, but always battling against the force which would cause them to revert. Even greater than these is the struggle of science to make man master of the entire globe until the sun goes down for the last time. At will, the deserts are converted into fertile fields; rich tropical areas are placed at man's disposal by scientific sanitation; the frozen regions to the north and south recede before his material progress. The conquest over climate is of such far-reaching possibility that as the earth gradually changes temperature, science will make man the master over this change, not completely, perhaps, but sufficiently to stretch the span of human existence upon this globe a little more nearly to the time when another planet sweeps too close and we melt once more into star dust.

But if the dark pictures of the dangers of science are true, if life like a pendulum swings from pain to ennui and back again to pain, if each of us would end all were it not that this demands a positive act, not against the will to live but against the animal that is our being, if all these things are true, should we then be grateful to the scientist who not only lengthens human life but the span of existence of the race?

For the answer, as we see it, to this recurrent question we must wait until we have looked somewhat more closely to see what we mean by science. So far, we have tacitly assumed by this term the exact sciences, those which are in the main responsible for our material progress, such as physics and chemistry. What of the contributions of the sciences which are less subject to mathematical treatment, such as psychology and sociology? We may question whether this distinction is a real one or merely one of convenience. Alchemy, the forerunner of chemistry, was far from mathematical. At a somewhat later period, Lavoisier introduced the extensive use of the balance into the chemistry of his day and it was then started on its way to becoming the highly mathematical science which it now is, with numerical tables and equations filling the pages of our journals of physical chemistry. As as-

tronomy developed, whole new branches of mathematics were built up to fill its needs. Perhaps as a science becomes older it becomes more subject to exact treatment, and the above distinction may be one of age only. Already in psychology we hear much of "the mysterious I. Q." and of correlation coefficients. Are these the first steps in the progression from numbers to ratios and then numerical relationships which mark the way to long and involved equations? If such is the case, the social and natural sciences will alike be exact.

Let us take a couple of examples from each class and see if we can distinguish a fundamental difference. Some one has said that when a feather falls to the ground, the earth is displaced from its axis. Not only this, but we can calculate the amount of displacement. True, the infinitesimal value which we obtain will not be the actual amount which the earth has moved from its axis in that instant, for at the same time there were other feathers falling, many leaves dropping from trees, trains crossing mountains and ships crossing seas. What, then, has our calculator done? He has limited the variables and given us the figure which the earth would move were all the rest of the mass of the universe stationary. Such is the legitimate procedure of the exact sciences. From the social sciences we learn that a certain percentage of any group may be classed as drunkards. Just as we limited our example in the previous case to a single feather let us here consider a single individual. But whereas with the group our percentage had a significance, now the figure is without meaning, no matter how much we limit our consideration of the forces bearing upon the situation—age, ancestry, environment, sex, color or creed, and we can not say that the individual is such a per centum drunkard nor can we say he is intoxicated such a *part of the time. Even if the individual is the child of drunken parents, we can* not say that he will become a drunkard, only that he may perhaps have a tendency toward the use of intoxicants. Doubtlessly no one would attempt to draw conclusions regarding the individual from group statistics in this particular case, but it would not be difficult to find slightly more complicated instances where the fallacy of this type of reasoning is less obvious and where one might be tempted to draw conclusions which would be equally untenable in passing from a statistical study to the consideration of a few or of an individual. Factors which tend to produce effects when the group is considered as a whole may be entirely lacking in certain members and thus we can not segregate the forces in discussing the individual as we did in the physical example. Too many unknown influences enter the social example to permit us to limit the system or its variables with any resultant meaning.

Or let us look at the matter from another viewpoint. We learn from chemistry that if sodium and chlorine are brought together common salt will result. Indeed, if a single atom of sodium is caused to react with a single atom of chlorine we may unhesitatingly predict that a molecule of sodium chloride, with all its characteristic properties, will be formed. May we likewise predict that the child of college graduates, each of high intelligence, will be the intellectual equal of its parents? In general, we find that superior parents will give birth to children of superior ability, but alas the same sociological data and psychological tests which give us this generalization have often shown that there may be a mite of truth in the highly exaggerated saying that the campuses of certain of our universities are flooded with the idiot children of the faculty. In our chemical example, limiting the units from gross masses to atoms brought no lessening of the accuracy of our prediction, but in our example from the less exact sciences we reached only "probably." And in this very difference may lie some of the hope for science as an agent of human welfare.

To be sure, no one would be so bold as to suggest that the social sciences will not become more exact and mathematical as time goes on. Indeed, this is doubtlessly what will occur. Nor should it be understood that statistical methods are not used in the exact sciences, for certain of the outstanding achievements of modern physics and chemistry are due to the application of such devices. But it seems more than likely that there will ever be a gradation in the sciences, from mathematics itself through the physical sciences, the biological sciences, the social sciences, even, if we may include it, to philosophy. And this gradation will depend upon the number of factors we are able to limit; the fewer we are able to limit the more will we be confined to group descriptions and indications rather than led to predictions and certainties.

Without this difference perhaps the world would force the results of the social sciences into the extreme utilitarian aspects of the exact sciences, and with studied social environment, ancestry and intelligence measurements, a new system of castes might grow up in which the "thousands who humble and nameless the straight, hard pathway trod" would be even more humble and nameless. Under such a system we might well wonder what would have become of Faraday, who was born the third child of a blacksmith and rose to first rank among the scientists of his day, or of the many artists and musicians who have risen above adverse circumstances of poverty and environment. The merits of the social sciences, too, may then be raised to question if we forget the limitations imposed by their general methods.

How then may we be sure for ourselves and posterity of the benefits of science without its dangers? Surely no one who has experienced the comforts of our materialistic progress would urge us to turn back in the hope of finding a Nirvana of contentment rather than to face the possible dangers of science. Nor yet would we wish blindly to pursue science if it is, as many have suggested, a powerful monster which may one day crush its creator. But conscious change for permanent betterment has never been in the direction of turning backward toward a darker age. We must ever face reality and take from each passing step the contributions which seem most fruitful for future welfare. Perhaps, after all, the pleasures of the present and the safety of the future lie in science, not in the exact sciences alone, nor yet the social sciences alone, but in the whole mass and development of organized knowledge and directed curiosity which we know as science and scientific research.

In viewing the possible dangers of the material development of exact science, many in that field have suggested that it is not their responsibility to what use society at large puts their discoveries. They have held that society and society alone is responsible for the use or misuse of the knowledge which is placed in its hands. But when we consider the fact that the army tests showed us to be intellectually a nation of sixth graders—and perhaps the rest of the world is not far different—we may suspect that the responsibility has been passed on to a not too well-trained guardian. It is almost akin to removing the responsibility from a parent for the consequences of permitting his child to play with firearms. If the exact scientist is not willing to take the responsibility for the results of his labors let him realize the fallacy of the belief that all men were created equal and pass the stewardship into the hands of those who are close to society and yet at the same time are members of the aristocracy of brains.

In this, perhaps, lies one of the broadest fields of the social scientists, to guide society into the right use of science, to protect mankind from its misuse, to turn the ever-increasing knowledge to the greatest happiness of the masses. Theirs is the task of keeping us from the devastations of war, of securing for us the right uses of the material progress afforded by science, of showing us how best to use the ever-increasing leisure which science has given us by decreasing the working hours, of guarding us from the hysteria of our fast methods of travel and communication. It is the opportunity of the philosophers and the social scientists to give us new faiths and ideals compatible with our new knowledge to replace those which biology and certain other branches of science have shattered. Theirs is the duty to show us that the doubts which they themselves have raised, that teachings such as those of Schopenhauer, though true perhaps in a measure, are but challenges to master the science of living.

In addition to the guidance which the social scientists can give us, we must have an ever-increasing spirit of science bred in the masses in order to protect us from the too material aspects of the exact sciences. Through formal education, popular lectures and books and articles made intelligible to the general public, the broad teachings of science will become part of the underlying thought of the race. Not that all will grasp the subject-matter of even a single branch of science, but that slowly the method of thinking and attitude of science will become a part of the everyday life of the people. All the qualities which are essential for the happiness of individuals living in large groups, for the progress and well-being of the race as a whole, result from the cardinal principles of science. They are the methods and attitudes of science, irrespective of the particular subject-matter. Patience, discipline, logical thought, original work, dignity of both mental and manual labor—these are to be found in science. Regard for truth and for the opinions of others, critical faculty, moral responsibility, self-sacrifice, higher views of life—all these are found in science. With a general assimilation of the methods of approach and teachings of science these qualities will slowly become the virtues of the race.

In viewing, then, this scientific age we should realize that we are dealing with a great two-edged sword which we can not treat compromisingly. We must face it wholly, with all its possibilities for good and evil. We must realize that we are working with a science of things and a science of men; that both need development, the one for man's material progress, the other to protect him from too much materialization. We should keep before us the certainty of prediction of the exact sciences and the equally helpful limitations of the social sciences. Lavoisier has been spoken of as the last chemist. Since his time chemists have been organic chemists, inorganic, physical, and specialists in many other branches. So with all science, great specialization is necessary, but at the same time for the greatest good to mankind cooperation both in its pursuit and its development is essential. Our encouragement, financial, moral and active, should be not to one science nor yet to one group of sciences, but to the whole mass of growing knowledge. We should take advantage of and encourage the labors of that group of workers who style themselves scientists and delve into the mysteries of nature without themselves being able to give a true—surely not a unanimous—reason for their zeal.

Many of the blessings of science can be obtained, in addition to the flexible grants of public monies, by the endowment of institutions of liberal charter. But let them be so flexible that as new needs arise—indeed, new sciences—we shall no longer be compelled to resort to the practice "where there's a will there's a lawyer." How much better would it be if the money left to institutions for public good should become the free and unencumbered property of the institutions after twenty years. Then we would no longer have to read into a gift for the care of young mothers a child guidance clinic, nor into a gift for beautifying a college campus a group of much needed buildings.

> Yesterday this day's madness did prepare;
> To-morrow's silence, triumph or despair.

Which of these will be to-morrow's fate will depend, perhaps, upon whether we are able to look upon science broadly and develop it purposefully.

JAN JACOBZ SWAMMERDAM

By Dr. HARRY B. WEISS

NEW JERSEY DEPARTMENT OF AGRICULTURE

DURING the Thirty Years' War the interior of The Netherlands was free from the devastating effects of Protestantism and Catholicism *en combat,* and the Dutch, under an economic policy directed by able administrators, grabbed the commerce of the world and increased their maritime power. With great success the Dutch East India Company exploited Asia and made war on Spain, and the West India Company operated in America and Africa. Every one was interested in making money. The Indian merchants and their friends wallowed in wealth and spent their money lavishly on silks, velvets, pearls, pictures, expensive furnishings, porcelain ware and objects of art from all parts of Europe and Asia. The people were prosperous, the arts flourished and Amsterdam was the world center of wealth and commerce.

Always fond of tulips and ornamental gardens, and with an abundance of money, the people spent freely on their gardens, and it was not strange that the passion for planting became general. This in turn stimulated the growing of tulips, and many persons saw therein an opportunity for becoming rich quickly. Various shades, colors and shapes were sought for and prices rose. Hundreds went into the culture expecting to become opulent over night by propagating the expensive varieties. Speculation and gambling replaced caution and thrift. Certain varieties brought astonishing prices; 2,500 gulden for a single bulb, and once 4,000 gulden. Brokers sold bulbs they did not have and wild speculation set in. Huge sums were made and lost. From 1634 until 1637, the tulip dementia raged and then the bubble burst.

During this craze was born one of the great biologists of the seventeenth century, John Swammerdam, in Amsterdam, on February 12, 1637, son of John James Swammerdam and Barentje Corver. From his birth he was surrounded by fossils, dried insects, minerals, stuffed animals, Chinese porcelain, curios from the Indies, pills, mithridates and elixirs, his father having been both a druggist and a collector whose assemblage of rare and unusual objects was locally celebrated. In such an atmosphere the boy developed a liking for natural history and he too collected—small animals, insects, from the surrounding streams and fields. And in addition, he was curator of his father's cabinet.

At first his education took the shape of a training for the church, and he studied Greek and Latin. However, feeling that he was not fitted for such a pursuit, he began, with his parents' consent, the study of medicine, and in 1661 traveled to Leyden, where he stayed for two years studying surgery with Van Horne and medicine with Franciscus Sylvius de la Boë, who was the first to evolve an entire system of medicine founded on chemistry. Here he became friendly with Nicholas Stensen, who in 1663 described the true structure of the heart, and with Regner de Graaf, of ovarian follicle fame. In 1663 he went to Saumur where he studied insects and made known in a letter to Stensen in 1664 the discovery of the valves of the lymphatic vessels. As Ruysch discovered the same thing a little later, Swammerdam thought that Ruysch had seen his drawings. Then to Paris where he was entertained generously by Melchisedec Thevenot, formerly the French king's minister at Genoa, who had a country home just outside of Paris. Here he met various notables, but being rather sparing of words he had very little to say at these gatherings.

Upon his return to Amsterdam he got permission to examine the bodies of hospital patients who had died and here he diligently studied anatomy, specializing on the structure of the spinal cord. Towards the end of 1666 he returned to Leyden for his degree, and in 1661 he was made a Doctor of Medicine and published his thesis on respiration in which he tried to show that "air entered the lungs because it became rarefied in the mouth and that the atmosphere became condensed within the chest when it expanded." This theory, first thought of by Descartes, was known as the Cartesian Circle. He also became quite expert in various methods of injection, and invented the art of wax injection which was perfected later by Ruysch, thereby greatly stimulating the study of minute anatomy.

Due to intense concentration on his work, Swammerdam's health began to fail about this time, and he was also stricken by malarial fever. Upon his recovery he discontinued his medical work for two years and again began the study of insects. In 1668 he had an opportunity to go to Florence. The Grand Duke of Tuscany, who visited Amsterdam in 1668 and who was taken by Thevenot to see Swammerdam and the museum, was so amazed by Swammerdam's skill in dissecting that he offered 12,000 florins for the collection, stipulating, however, that Swammerdam should accompany it back to Florence and enter his service. This Swammerdam refused to do, probably because court life did not appeal to him, but perhaps mainly because he was Protestant and could not accept the teachings of Roman Catholicism. His friend Stensen had become in 1666 the head of a hospital in Florence and physician to the duke, and a year later he accepted the Catholic faith and from then on took orders until 1675, when he was made a priest. He then discontinued his scientific studies and a year or so later he was made a bishop and returned to the northern Protestant countries as a missionary.

In 1669 Swammerdam published his "General History of Insects" which was dedicated to the Amsterdam senate. Some of his own money had been spent in the collection of specimens for this work, and its publication did not add to his income. Such an unprofitable course displeased his father, who urged him to forget insects and practice medicine. Although this was good advice from a financial viewpoint, Swammerdam was reluctant to follow it. At this time, suffering from another attack of malaria, he retired to the country to regain his health. Once in the fields, he was soon hard at work again on his beloved natural history, studying among other things the life history of the hive-bee and of the Ephemera.

In ill health, and depressed, his thoughts turned more and more to religion and while in this frame of mind he was greatly impressed by some of the ideas of Antoinette Bourignon, a Flemish religious zealot, who scattered her divine wisdom and emotional mysticism in the Netherlands and adjoining parts of Germany. As Swammerdam, during the remainder of his life, was guided more or less by her teachings, it is of interest to know their content.

Antoinette Bourignon, born at Lille in 1616, apparently had a hectic time during most of her life. As a child she was positively ugly, but precocious, with a decided flair toward religious mysticism. When she was about twenty her father tried to force her into a marriage, but she escaped and later, upon the death of her father, sued her stepmother and was awarded all her father's property. From then on, her activities included admission to a convent where she gathered followers, the founding of an orphan home for girls, accusations of cruelty to her charges, flight, a period of delight among the heretics of Amsterdam, an attempt to establish a community house for her disciples on the island of Nordstrand in the North Frisian Sea which involved her and deCort in financial difficulties ending with his premature death in prison, another flight, hostilities with the authorities of Husum, where she set up a printing press, then refuge by the eccentric Colonel LaCoste followed by a quarrel during which he formally accused her of sorcery in 1679, another flight, and concealment until her death in 1680.

She was a second-rate prophet of Quietism which spread over the religious life of Europe during the latter part of the seventeenth and early part of the eighteenth centuries, gaining converts among both Protestants and Catholics. In the "Encyclopaedia of Religion and Ethics," Quietism is defined as "the exaggeration and perversion of the mystical doctrine of interior quiet." Its doctrines were passivity, the surrender of the soul to God once for all in one act, never to be repeated, and an altruistic love of God without hope of reward or fear of punishment. Antoinette's system was personal; she was "the bride of the Spirit," the "woman clothed with the sun," the "channel of revelation." She taught that the "human nature of Christ was dual, and one part was liable to sinful corruption; similarly every man has a dual nature, one part being distinctly good; as the will is entirely free, any one may throw the balance on the right side and obtain perfection here." Seven volumes of her works were published at Amsterdam in 1687 and an English transcript which appeared in London in 1699 had some influence in Britain. It is recorded that in 1661 at Lille, one of her pupils confessed, "The Devil gives them a Mark, which marks they renew as often as those Persons have any desire to quit him. The Devil reproves them the more severely, and obligeth them to new Promises, making them also new Marks for assurance or Pledge, that those Persons should continue faithful to him." This mark or "seal of Satan," on the body, was supposed to be almost positive proof of the identity of a witch.

When Madame Bourignon was in Holstein, Swammerdam wrote to her about his incertitude and as a result of her advice, he resolved to discontinue work on mundane enterprises and to try to "make his peace with God." However, he continued his studies, especially those on bees. In fact he was perpetually examining, dissecting, describing and drawing, from early morning through the blazing heat of the day until afternoon, with the result that his eyes became weakened from constant use and his health impaired from such confinement. In addition he was divided mentally between his impulse to investigate and his desire to devote himself to God. Macgillivray states that Swammerdam, after finishing his work on the structure of bees, was filled with remorse and gave the manuscript to a friend, regardless of its future. At another time he determined to devote the remainder of his life to the "cultivation of Christian piety," in which Madame Bourignon encouraged him, and with this in mind, tried to sell his collection, applying to Thevenot and Stensen to find purchasers. Stensen advised him to embrace the Catholic faith and come to Florence, promising him his aid in inducing the duke to buy it, but to such an offer Swammerdam was deaf. It was about this time that he arranged and catalogued the specimens in the museum.

In 1675 his history of the Ephemera was published, undoubtedly with fiscal help from some one, perhaps his father, and upon approval from Madame Bourignon. This completed, he resolved again to lead a religious life and went to Holstein to consult Madame Bourignon personally. At that time the Lutheran ministers were making things hot for Antoinette and she prevailed upon Swammerdam to go to Copenhagen and petition the king of Denmark for permission to live in his kingdom. This he did in company with another disciple on March 25, 1676. The Danish king, however, refused to welcome Antoinette, and Swammerdam returned to Amsterdam on June 16 and found his father quite out of patience with his late behavior. Then his sister, who kept house for them, married and his father deciding to live with his son-in-law, Swammerdam found himself without a home and with an allowance of only 200 florins. The next year his father died leaving him heir to enough property for his support, but he became involved in disputes with his sister over the division of the property, and this together with religious worries ended in an attack of malaria with complications, which lasted three months and from which Swammerdam really never recovered. He made his will on January 25, 1680, leaving to Thevenot all his original manuscripts and drawings, which were at that time in the possession of Herman Wingendorp, of Leyden, to whom they had been sent for translation into Latin. His property he willed to Margaret Volckers, one of his executors and wife of Daniel de Hoest. He died February 17, at the comparatively early age of 43 years.

Swammerdam's "General History of Insects" deals at length with insect transformations and the erroneous ideas of the celebrated Harvey, discoverer of the circulation of the blood, whose knowledge of development had been obtained from the study of vertebrate embryos. Harvey said that insects were generated by chance, which aroused Swammerdam's disgust, and he combats this and other mistaken notions of Harvey at great length. Both the "General History of Insects" and the "Ephemera" were later incorporated with the "Biblia Naturae."

His "Biblia Naturae" was not published until 1737–38 and the manuscripts had a precarious and curious history. Thevenot, to whom Swammerdam had willed them, attempted several times to secure them from Wingendorp through Dr. de Hoest, but Wingendorp, who was poor, and not altogether honest, tried by various pretexts to claim ownership. Finally a suit was instituted which Thevenot won in 1682. After Thevenot's death they were bought by the painter Joubert, whose heirs sold them for fifty French crowns to the anatomist Joseph du Verney, who neglected to do anything with them. Finally, Boerhaave, the distinguished Dutch physician, clergyman, student of botany and chemistry, hearing that they still existed in Paris, asked his friend William Sherard, who was going to visit that city, to look into the matter for him. This Sherard did and Boerhaave, who wanted Holland to have the honor of publishing them, succeeded, after some help from influential friends, in purchasing them in 1727 together with the drawings, for 1,500 French florins. As a result, Swammerdam's works were published in two folios in 1737–38, illustrated by fifty-three plates and accompanied by a new Latin version by Gaubius. In 1758 Hill's English edition was published.

Swammerdam's classic "Bible of Nature" includes detailed accounts of the life-history and anatomy of the bee, the gnat, the ephemera, the dragon-fly, gall insects, the water-flea, the snail, the frog, etc., accompanied by marvelous drawings. It contains many original and accurate observations and refutations of the mistakes of previous writers. Miall discusses at some length Swammerdam's work on the bee, the snail and the frog and praises it highly. In fact Swammerdam's work has never lacked admirers. Wheeler in his recent translation of Réaumur's "Natural History of Ants" states that Swammerdam was the first to prove that "The common ants of northern Europe do not harvest and store seeds."

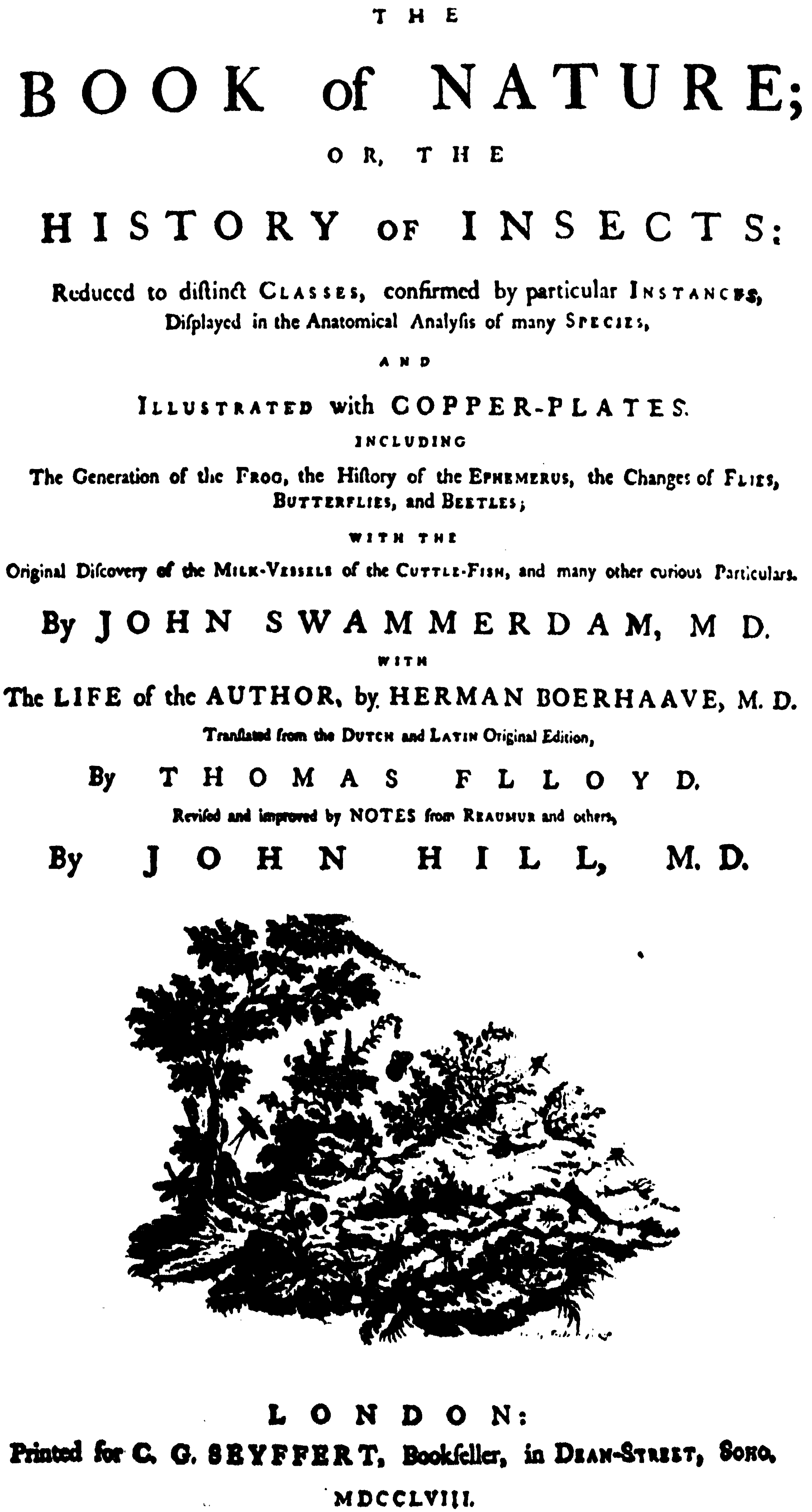
Swammerdam was thoroughly familiar with his subject and its literature and the work of Ray, Redi, Malpighius, Lister, Leeuwenhoek, Muffett, Harvey, Goedaert, etc., often calling attention to the mistakes of these authors. He spent little time in rehashing the work of ancient writers and stuck closely to his subject, although at times digressions and sermonettes are quite apparent. Frequent mention is made of God and His works, showing Swammerdam's religious nature, and the following quotation indicates how deeply he felt about such matters. "That vulgar opinion, more worthy of brutes than of rational beings, which ascribes the birth and growth of animals to putrefaction and chance, is diametrically opposite to sound reason, and favours rankly of atheism. It has not even the least shadow of experiment or observation to support its truth; but is founded altogether upon sloth, prejudice, stupidity, and error; all which is the more obvious, as in the smallest animals we constantly every where find as much order, contrivance, beauty, wisdom, and omnipotence in the Great Architect, as are shown in viscera or bowels of the largest animals."

In his classification he used developmental characters while his contemporaries utilized superficial, physiological and morphological ones. As a result, scorpions, spiders, and centipedes according to Swammerdam fell into the first of his insect orders because, like the lice, their development was direct and without transformation.

It is difficult to improve upon Miall's estimate of Swammerdam—"That he offered the first scientific account of those transformations which had hitherto been so anomalous and perplexing; that he gave a powerful impulse to the comparative study of animal structures; that he did something for the improvement of zoological system; that he illustrated by a series of examples admirably worked out that method of studying structure and life-history by means of concrete animal types, which still holds its ground as the best form of elementary instruction in biology, and that he made important contributions to experimental physiology and embryology."

Swammerdam was an excellent technician, unequalled in his day. According to Boerhaave, he had numerous lenses and would proceed from one to another. His dissecting instruments which he used so skillfully consisted of fine scissors, knives, lancets and style, some of which were so fine that they had to be sharpened under a magnifying glass. His drawings have always excited admiration, and justly so, as one can see by the few examples that accompany this account.

It is strange that such an independent thinker and investigator as Swammerdam should have fallen so completely under the influence of Madame Bourignon, who from all accounts was positively unpleasant to look upon and erratic, miserly and contumelious to boot. However, Swammerdam was brought up on the Bible as nearly all Dutchmen were, and religion occupied a large share of his thoughts. And although Antoinette Bourignon may have been everything that has been written about her, the fact remains that she had a respectable following at times, due either to the intellectual or emotional appeal of her ideas or her personality or both. Perhaps Swammerdam was attracted by her independence in religious matters. For after all she was really revolting against current and commonly accepted interpretations which of course



THE

BOOK of NATURE;

OR, THE

HISTORY OF INSECTS:

Reduced to diſtinct CLASSES, confirmed by particular INSTANCES,
Diſplayed in the Anatomical Analyſis of many SPECIES,

AND

ILLUSTRATED with COPPER-PLATES.

INCLUDING

The Generation of the FROG, the Hiſtory of the EPHEMERUS, the Changes of FLIES,
BUTTERFLIES, and BEETLES;

WITH THE

Original Diſcovery of the MILK-VESSELS of the CUTTLE-FISH, and many other curious Particulars.

By JOHN SWAMMERDAM, M. D.

WITH

The LIFE of the AUTHOR, by HERMAN BOERHAAVE, M. D.

Tranſlated from the DUTCH and LATIN Original Edition,

By THOMAS FLLOYD.

Reviſed and improved by NOTES from REAUMUR and others,

By JOHN HILL, M. D.

LONDON:

Printed for C. G. SEYFFERT, Bookſeller, in DEAN-STREET, SOHO.

MDCCLVIII.

PLATE I.—TITLE PAGE OF THE HILL EDITION OF SWAMMERDAM'S
"BIBLIA NATURAE"

accounted for her unpopularity with both Protestant and Catholic professional defenders of the faith. In a way Swammerdam was simply extending his zoological habit of thought to matters of theology, and one should not deny him this right. At times he may have been torn between the love of his work and the idea that such ambition was sinful, but as he continued his research in natural history, one is warranted in assuming that the urge to express himself scientifically won out, and the sermonettes in his "Biblia Naturae" may have been his way of justifying the work. Whatever Madame Bourignon's influence may have been, Swammerdam did not, like Botticelli under the influence of Savonarola, burn his drawings and for this posterity should be thankful.

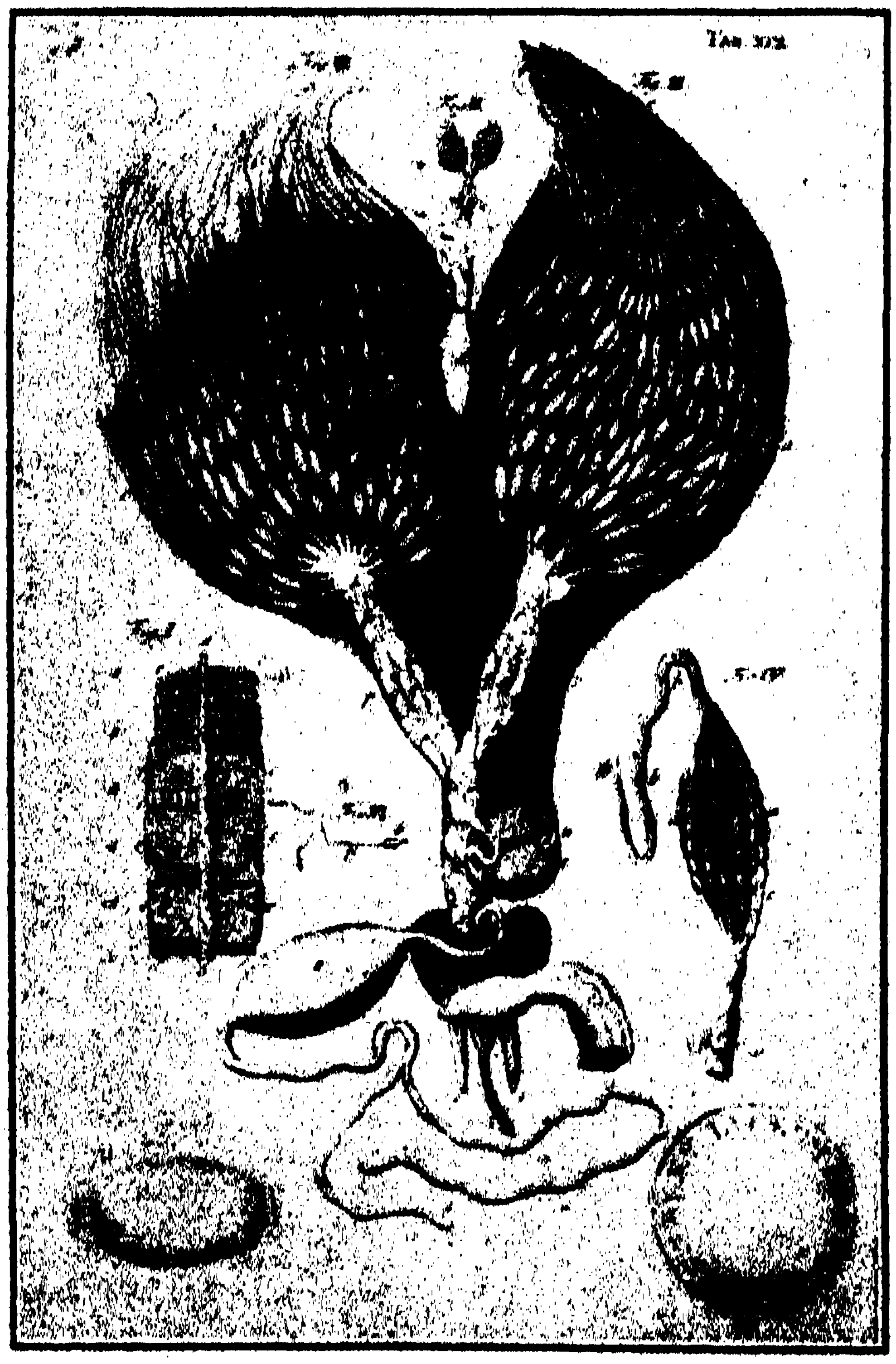


PLATE III.—PLATE XIX OF THE HILL EDITION OF "BIBLIA NATURAE"
FIG. I, THE BEE'S HEART; II, OVARY OF BEE; III, OVARY MAGNIFIED; IV, OVARY OF WASP; V, EGG OF A BEE; VI, POISON SAC OF BEE.

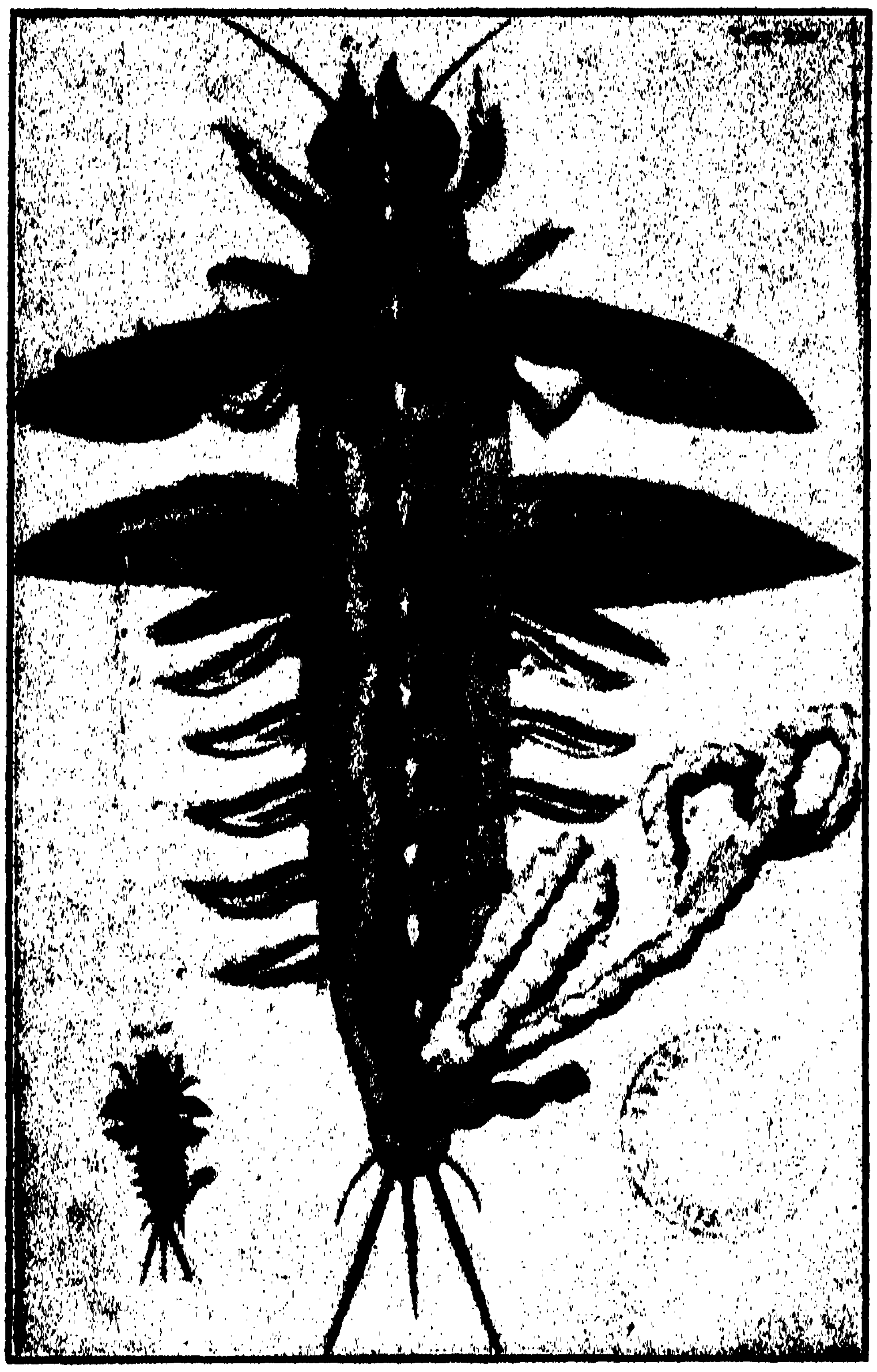


PLATE II.—PLATE XIV OF THE HILL EDITION OF "BIBLIA NATURAE"
ENTITLED, "A DISSECTION OF THE WORM OF THE EPHEMERUS."

During Swammerdam's lifetime, far-reaching political and economic changes took place in the Netherlands. The end of the Thirty Years' War in 1648 found the provinces almost at the height of their prosperity, and a few years later their trade was almost five times larger than that of England. France was dissatisfied because the Netherlands had broken faith with her, and England was jealous of Dutch affluence. The politicians of the seven Dutch republics wrangled among themselves for power, and foreign politics was neglected. Then came the Anglo-Dutch war of 1652, provoked by England, Cromwell's navigation laws which seriously crippled Dutch trade, and the loss of Brazil to the Portuguese. Failing to strengthen their federation and to improve their military and political organization, the

Netherlands when they were attacked a second time by England, lost more trade, their North American colonies and their maritime supremacy. London became the chief commercial city of the world and Amsterdam declined. Then came a tariff war with France, imitated successfully by other nations, all to the Netherlands' disadvantage, until in 1672 they were encompassed by foes abroad and threatened by enemies at home. Disunited and unprepared the provinces were attacked by England again and invaded by France, with the result that they went to pieces completely and were saved only by foreign help and by the people rising against the oligarchs who were responsible for the maladministration of the war and for their hardships.

When Swammerdam died, the Netherlands were poverty stricken, trade and industry were disabled, debts had piled up, much low-lying land had become unproductive as a result of the sea-water with which it had been inundated, and the nation was a second-class power. It does not seem to be recorded whether Swammerdam took any interest in political or economic affairs, or not. As a scientist and ordinary citizen he was occupied by his own affairs and probably content to allow the destiny of the country to remain in the hands of the professional politicians and capitalists. He had domestic worries; he was frequently sick and at times in need of money; he thought deeply upon religious matters, and was unhappy; he thought deeply and worked independently in natural history and was a great biologist.

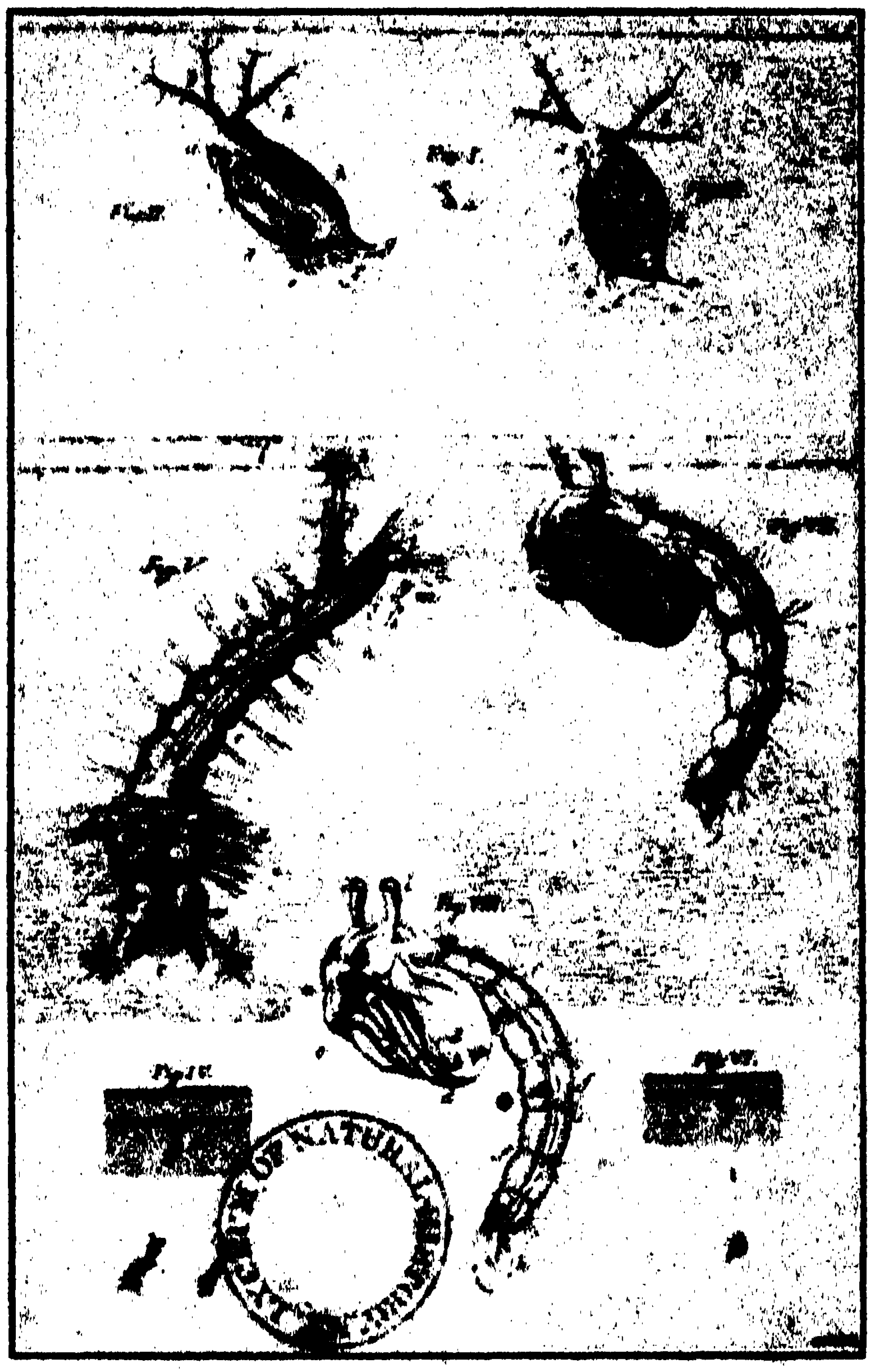


PLATE IV.—PLATE XXXI OF THE HILL EDITION OF "BIBLIA NATURAE"
FIGS. I, II, III, "THE HISTORY OF THE ARBORESCENT FLEA." FIGS. IV TO VIII, "A SHORT HISTORY OF THE GNAT."

BIBLIOGRAPHY

Amicis, E. de.
"Holland." (Phila., 1894).
Barker, J. E.
"The Rise and Decline of the Netherlands." (New York, 1906).
Cumston, C. G.
"An Introduction to the History of Medicine." (New York, 1926).
Encyclopaedia of Religion and Ethics (1921).
Kurtz, J. H.
"Text Book of Church History." (Phila., 1892).
Macgillivray, W.
"Lives of Eminent Zoologists." (Edinburgh, 1834).
Miall, L. C.
"The Early Naturalists, Their Lives and Work." (London, 1912).
New International Encyclopaedia. (New York, 1916).
Réaumur, R. A. F. de.
"The Natural History of Ants." (Wheeler trans., New York, 1926).
Rogers, J. E. T.
"The Story of Holland." (New York, 1889).
Summers, Montague.
"History of Witchcraft and Demonology." (New York, 1926).
Swammerdam, John.
"Biblia Naturæ." (Hill edition, London, 1758).

NIGERIA

By Professor A. S. PEARSE
DUKE UNIVERSITY

NIGERIA is a rich country which contains eighteen million people; about one tenth of the population of Africa. It exports palm oil, peanuts, cocoa, hides, cotton, rubber and is quite unhealthful, the climate being hot and humid. Malignant malaria is prevalent and is often followed by blackwater fever. West African yellow fever is usually sporadic among white people, but often fatal. Plague is continually present in the south. Filarial worms, chigoe fleas, ticks, sand flies and other parasites at times make life very disagreeable. In the south diseases carried by tse-tse flies exterminate most large animals, and in many districts human sleeping sickness is endemic. In the drier northern country toward the desert and in the highlands of the Bauchi Plateau large game abounds in many localities and cattle and horses are kept by the natives. Notwithstanding the hardships which attend daily life, Nigeria is an interesting and charming country. It is well governed by a hardy, hard-drinking, gentlemanly and competent little group of British administrators. It is peopled by primitive, cheerful natives, who have an aged but crude civilization. It contains many interesting plants and animals.

Nigeria is divided into six rather clearly defined climatic and vegetational zones, which cross the country from east to west. (1) Along the coast is a series of lagoons, which are bordered by mangroves and other plants that live in brackish water. (2) The freshwater swampy zone supports rather open for-

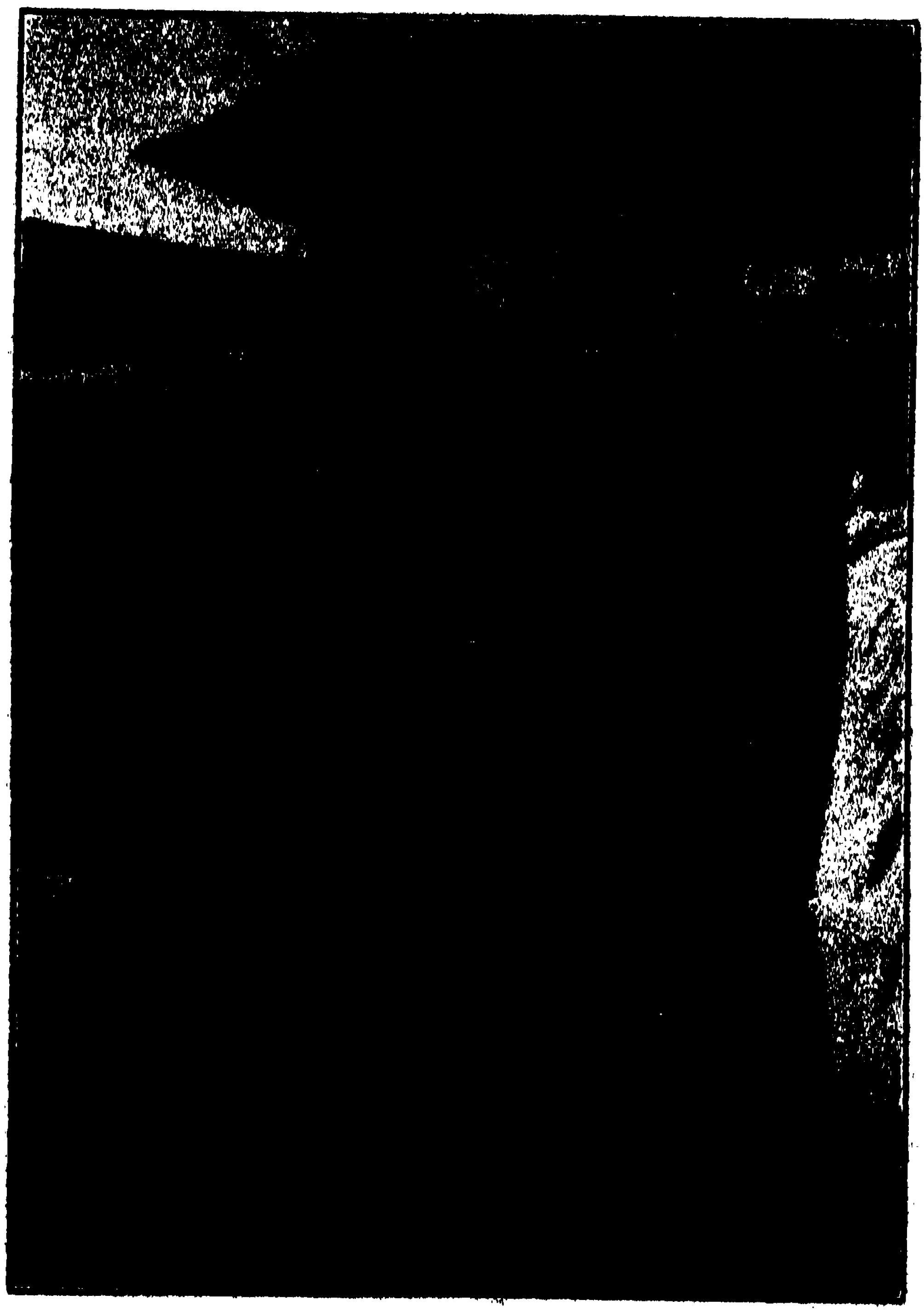
PALM WINE COLLECTORS

A PALM WINE COLLECTOR

ests which contain some valuable trees and, among other products, yields fibers, poles, thatch and some timber. (3) The rain forest, or moist tropical evergreen forest, contains a great variety of trees which are often lofty (over 150 feet) and buttressed. The trunks and branches are covered with epiphytes. Here grow mahogany and other valuable woods. The oil palm, *Elaeis Guineensis,* yields more wealth than any other plant in Nigeria. (4) The monsoon, or mixed deciduous, forest averages about 150 feet in height. It persists where there is a well-defined dry season, during which many of the trees shed their leaves. (5) The savanna is dryer. It consists of scattered trees with twelve-foot guinea grass between. The grass is burned over each year at the beginning of the dry season. (6) The steppe is characterized by thorny shrubs, euphorbias and certain trees. In the north it merges into a bare, sandy desert.

In 1926 the writer worked with the International Health Board in Nigeria and made certain observations on plants and animals which may be of interest. Three months were spent in and near Lagos, on the coast. Here the mangroves, estuaries, rivers and rain forest were studied from July to October. During six weeks at Ibadan animals in the guinea grass were observed, and short trips were made to Oyo and Ife, where there is a luxuriant monsoon forest. In November and December two weeks were spent at Kano, on the edge of the desert.

A PALM WINE COLLECTOR



TREADING OUT PALM NUTS FOR OIL

The Lagoons along the Coast

The lagoons and estuaries are lined with mangroves. On the roots of these plants live crabs and climbing fishes. Among the branches squawking birds and monkeys move about. The water teems with fishes and shrimps. Traps and nets set by the natives are seen everywhere. Dug-out canoes ply back and forth. Tse-tse flies are a great pest

PALM WINE DRIPPING INTO A CALABASH FROM THE CROWN OF A FALLEN PALM

LOADING COCOA

DRYING COCOA

in many localities, particularly along the rivers and in the shade of the mangroves.

The Swamp Forest

These forests consist of plant associations that are permanently submerged in freshwater. They are the home of two piassava-yielding palms, *Raphia Hookeriana* and *R. vinifera*. In addition to supplying the natives with fiber, their leaf stalks are used as poles for propelling canoes, the leaves as thatch, the macerated nuts for stupefying fish, and the stems are tapped for "tombo," or palm wine.

As one goes in a canoe through the swamp forest squirrels and monkeys scamper about in the trees. The ponderous Nigerian toucans squawk and beautifully iridescent little kingfishers sit motionless on the branches which project over the water. The beauty of everything more than compensates for the tse-tse bites endured.

The Rain Forest

The rain forest grades more or less insensibly into the swamp forest. It consists of gigantic broad-leaved trees, palms and other vegetation which make a continuous leafy canopy. Epiphytes are common and in favorable situations cover the trunks of trees completely. Some of the largest trees in the world are found in these forests. Many of the trees are buttressed.

Near Lagos the natives find rich soil in forest clearings. They raise cassava and such fruits as oranges and papaya.

CRACKING PALM NUTS FOR OIL

There are no large animals in Southern Nigeria on account of the tse-tse. The etu is a little deer (*Neotragus pygnaeus* Gray), about as large as a rabbit, which browses in the forest at night. Lemurs (*Perodicticus potto* Geoff.), lizards, snakes and chameleons lurk among the branches of the trees. Evil-smelling civet cats (*Atilax paludinosus* G. Cuv.) and genettes (*Genetta tigrina pardina* Geoff.) hunt in the underbrush at night. The former are very fond of land crabs; the latter prey mostly on mice and are slender, vicious creatures—supple and sinuous.

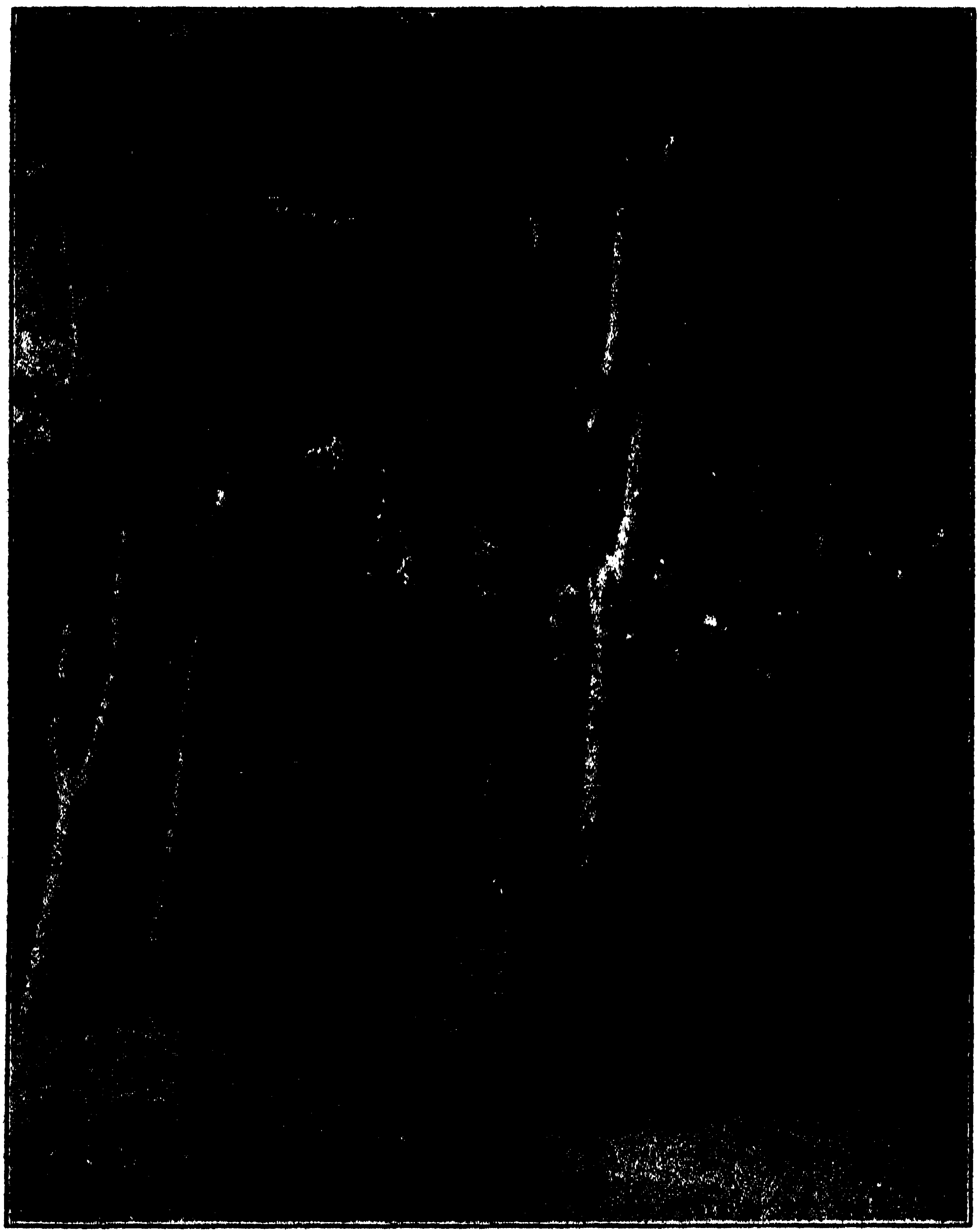
Rodents are abundant everywhere and, as there is little other fresh meat to be had, are much sought after by the native Yorubas for food. During the day several species of squirrels run about in the trees. In grassy open spaces a striped mouse and a pigmy mouse are found. These two species also occur in the savanna farther north. At night more than a dozen species of mice and rats are active. The large gambian forest rat (*Cricetomys emini* Wroughton) lives in burrows. It has loose cheek pouches for carrying food and is a great pest in the peanut fields. The most curious of the rodents is perhaps the gigantic "cut-grass" (*Thrymonys swinderianus* Temm.), which has a stubby tail and is shaped somewhat like a guinea pig.

ETU DEER

A GIANT COTTON TREE WITH BUTTRESSES

Along the forest trails at intervals the nests of the social weaver birds are conspicuous. The parrots are not so noisy as those in South America, but there are other birds which keep chattering. In the evening a little bird sings a plantive and sweet but monotonous song which reminds one of the American chickadee. Giant goatsuckers roost in the trees during the day and are often seen on the trails at night. A favorite roosting place of the large fruit bats is along the midribs of cocoanut palms.

Ants are found everywhere. There are travelling species which have no permanent home and a variety of spe-



RUBBER TREES

cies which live in underground burrows. One species builds a nest by fastening the living leaves of shrubs together into a neat globe. The forest termites do not build very large nests, but their architecture often takes fantastic forms. One species builds little towers like mushrooms in the deepest shade of the forest. The Yorubas do not disturb these towers because they firmly believe them to be the homes of devils.

The open places and thickets along the borders of lagoons and streams are favorite resorts for land crabs. In such situations civet cats, storks and great monitors hunt. One monitor examined by the writer measured forty-six inches in length. It was kept in captivity for a couple of weeks and proved to be a savage creature, which ate two or three crabs daily. My native hunter maintained that monitors become quite tame if kept in captivity for a long time. Among the larger animals in the Nigerian rain forest are the elephant, dwarf buffalo and deer. Few of these larger

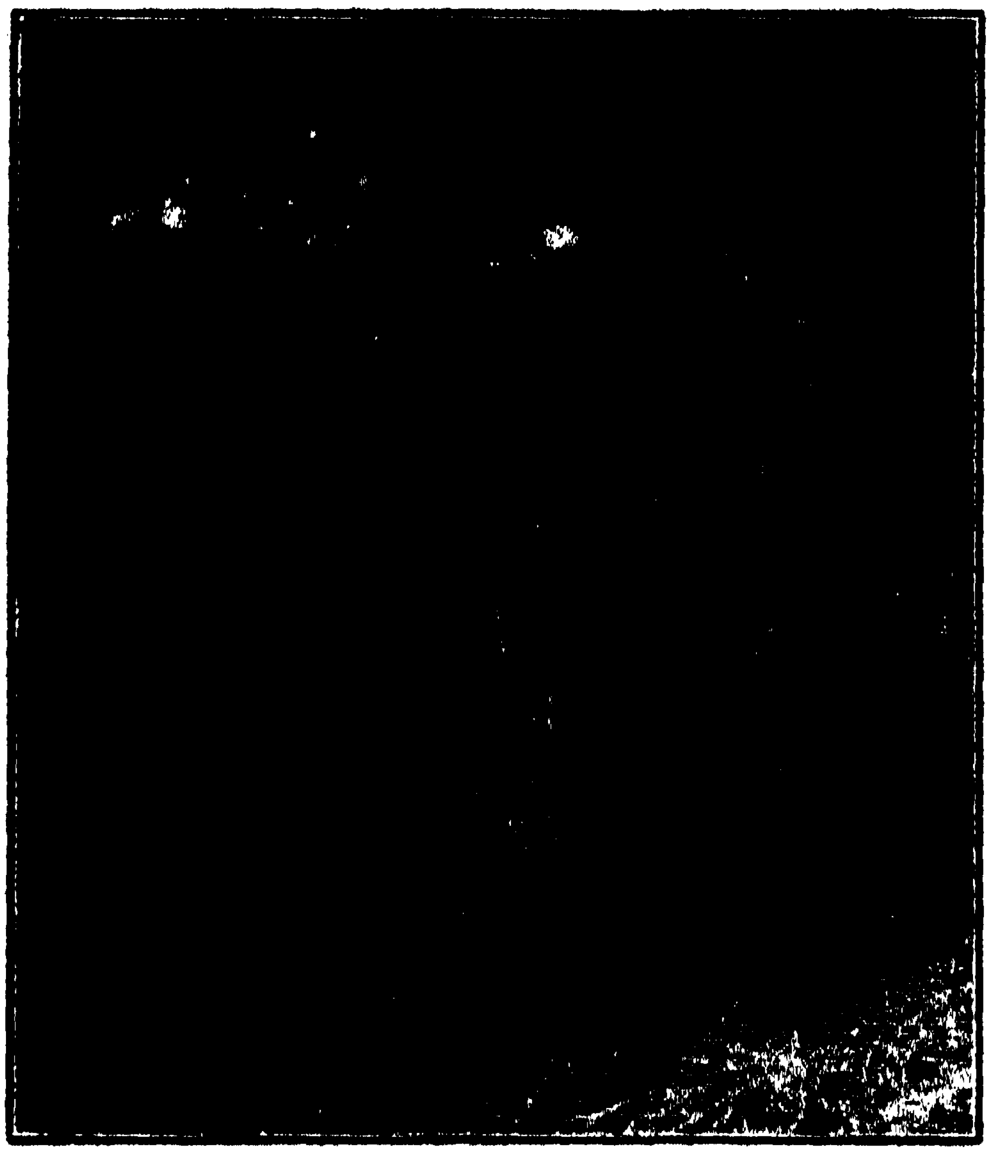
WEAVER BIRDS' NESTS IN PALMS

animals were seen by the writer, as he was in tse-tse fly country.

THE SAVANNA

The "guinea grass" grows for hundreds of miles through Nigeria. It consists of several species of plants which stand twelve to fifteen feet in height. Among these grasses grow scattered trees which become fewer as one travels north. In the Guinea grass live many game animals—elephant, hartebeest, giraffe, rhinoceros, lion, cheeta, hyena and hare. At the beginning of the dry season the grass is burned over. During December and January Nigeria is full of fires. After the burning, the hunting season begins and game animals commonly take refuge in little patches of grass which have escaped the fires or in the fringes of forest along streams. In the Guinea grass natives farm mostly on virgin soil, new areas being broken up after each annual burning over. The crops are chiefly maize, cassava, yams and fruits.

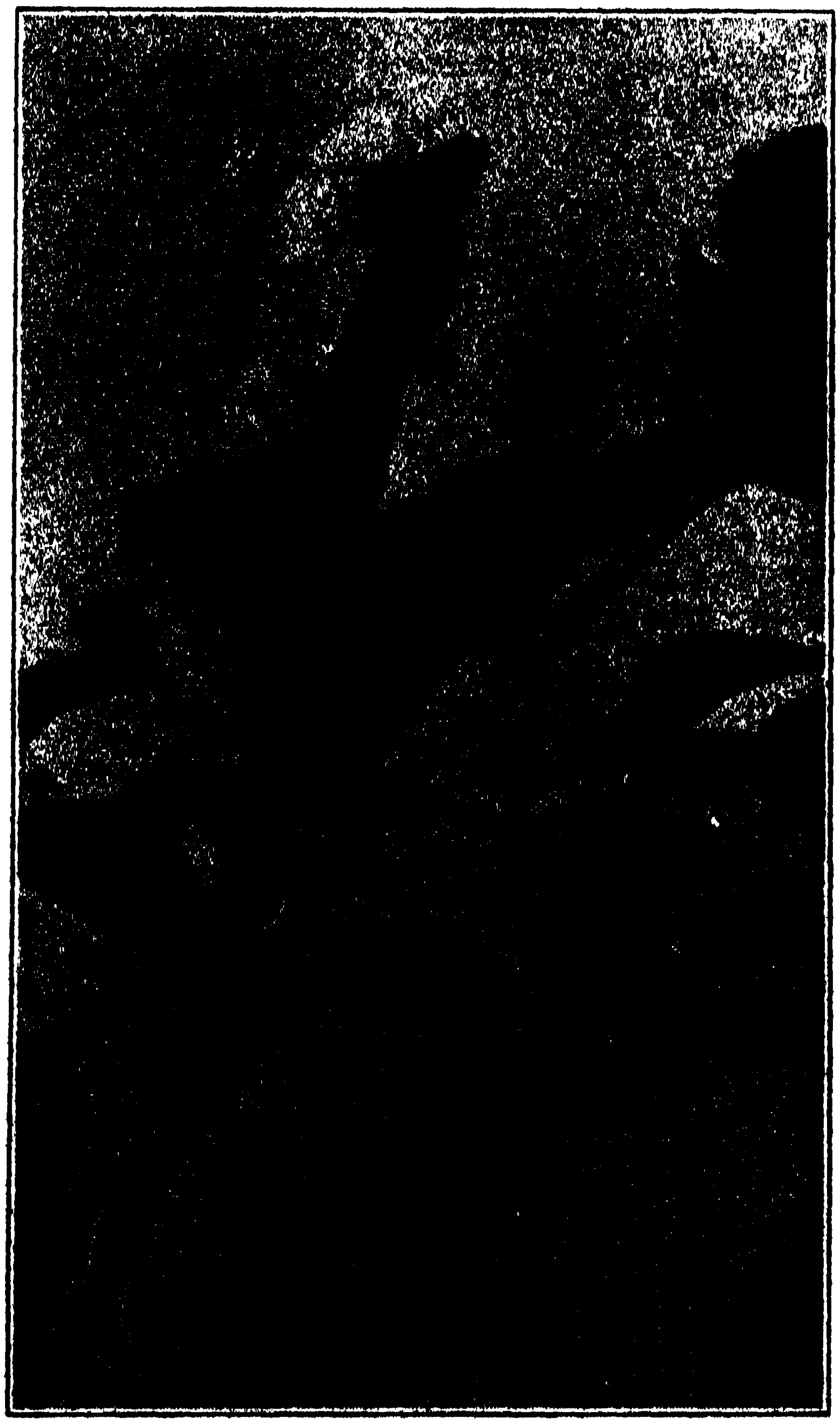
The Guinea grass is a monotonous habitat and appears on casual observation to be scantily populated with animal life, but besides the large game animals it shelters many small rodents



CASSAVA GOING TO MARKET

A CASSAVA TWIG IS STUCK IN THE GROUND, WHERE IT TAKES ROOT AND SENDS UP SHOOTS

and birds, such as bush fowl, which is much like a grouse, and wild guinea fowl. The termites which build mounds on the savanna near the Niger River at Jebba construct fantastic towers which remind one of church spires and are fifteen feet in height.



CHAMELEON

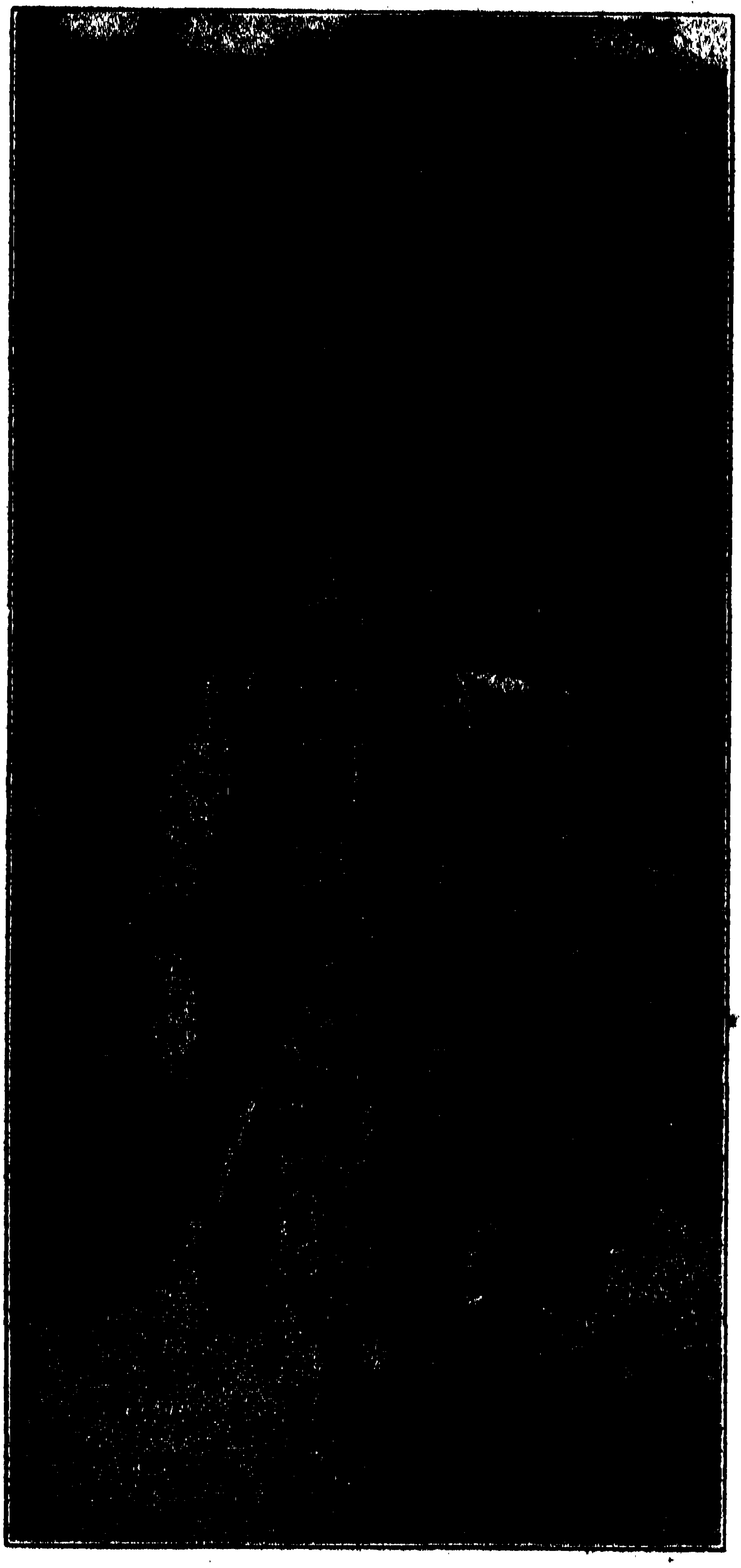
Swarms of foraging ants are frequently met with in the Guinea grass. The commonest species is a small dark ant which robs termites' nests of their young. There is no honor among thieves! The fly sits waiting beside the roadway of the robbers. With a favorable opportunity it pounces on the laden caravan and throws an ant with its burden to one side. It then takes the termite away from the ant and sucks out its juices.

The Steppe and Desert

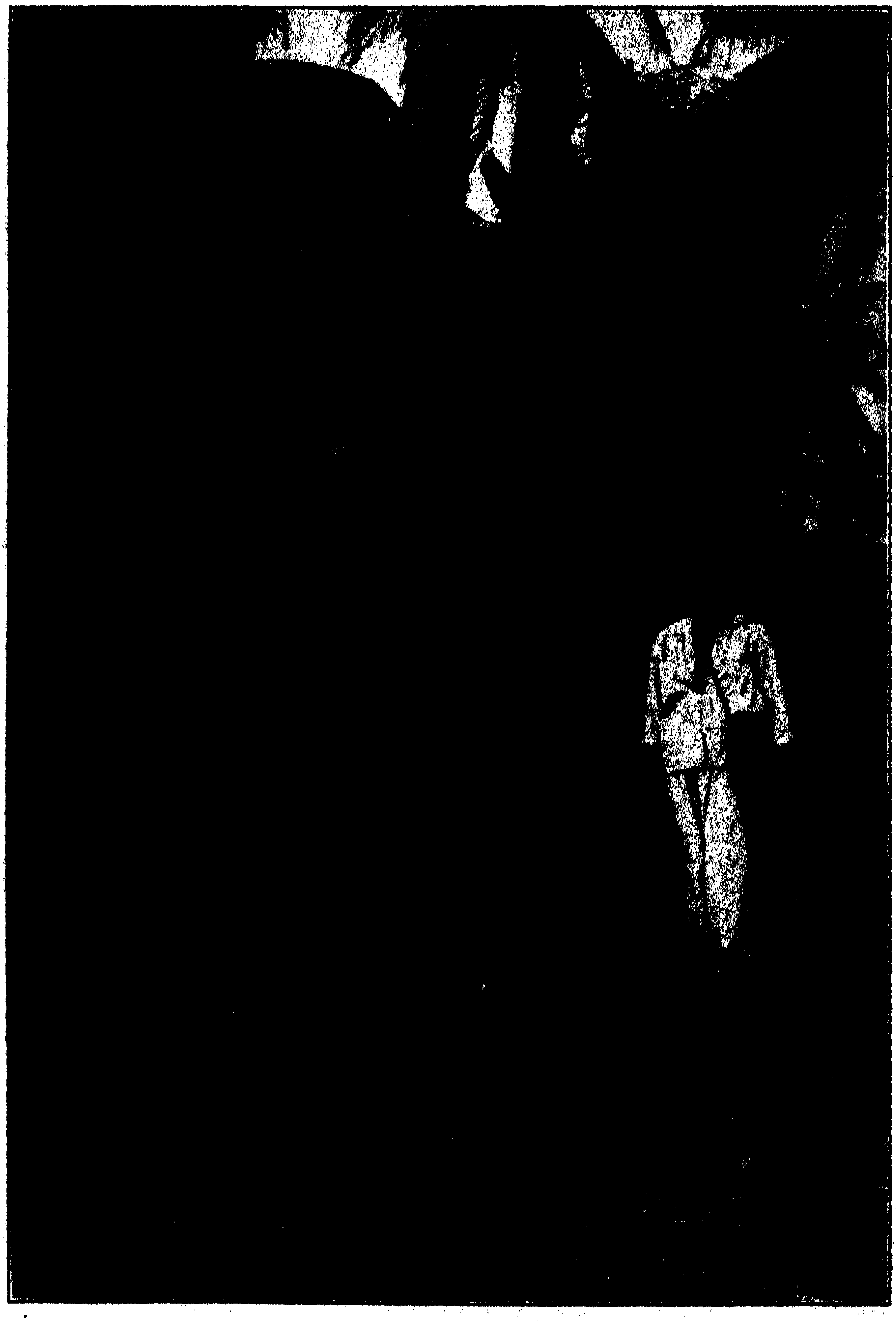
At Kano the writer had an opportunity to see some of the life in the desert. The vegetation consists of euphorbias, grasses, acacias and other shrubs. There are few types of animals—gazelles, sandgrouse, rats, mice, jerboas, shrews, hedgehogs, crows, buzzards and other birds. There are no proper house rats, but the native dwellings shelter shrews and jumping mice. There is a species of Gambian rat which is lighter colored than that in the forest. Caravans of camels, donkeys and bullocks are continually arriving from, and departing for, the desert. At the beginning of December they were mostly laden with peanuts and goatskins from the north.

On several nights trips were made along the trails with a jacklight and a number of hedgehogs were captured. A hedgehog is very entertaining. When handled it folds its head and legs into the pit of its stomach, pulls its skin up to cover these appendages, and contracts a muscular puckering string which encloses them in a bodily bag. Thus the hedgehog becomes a spiny ball which, to mix a metaphor, is a hard nut to crack.

A HEDGEHOG



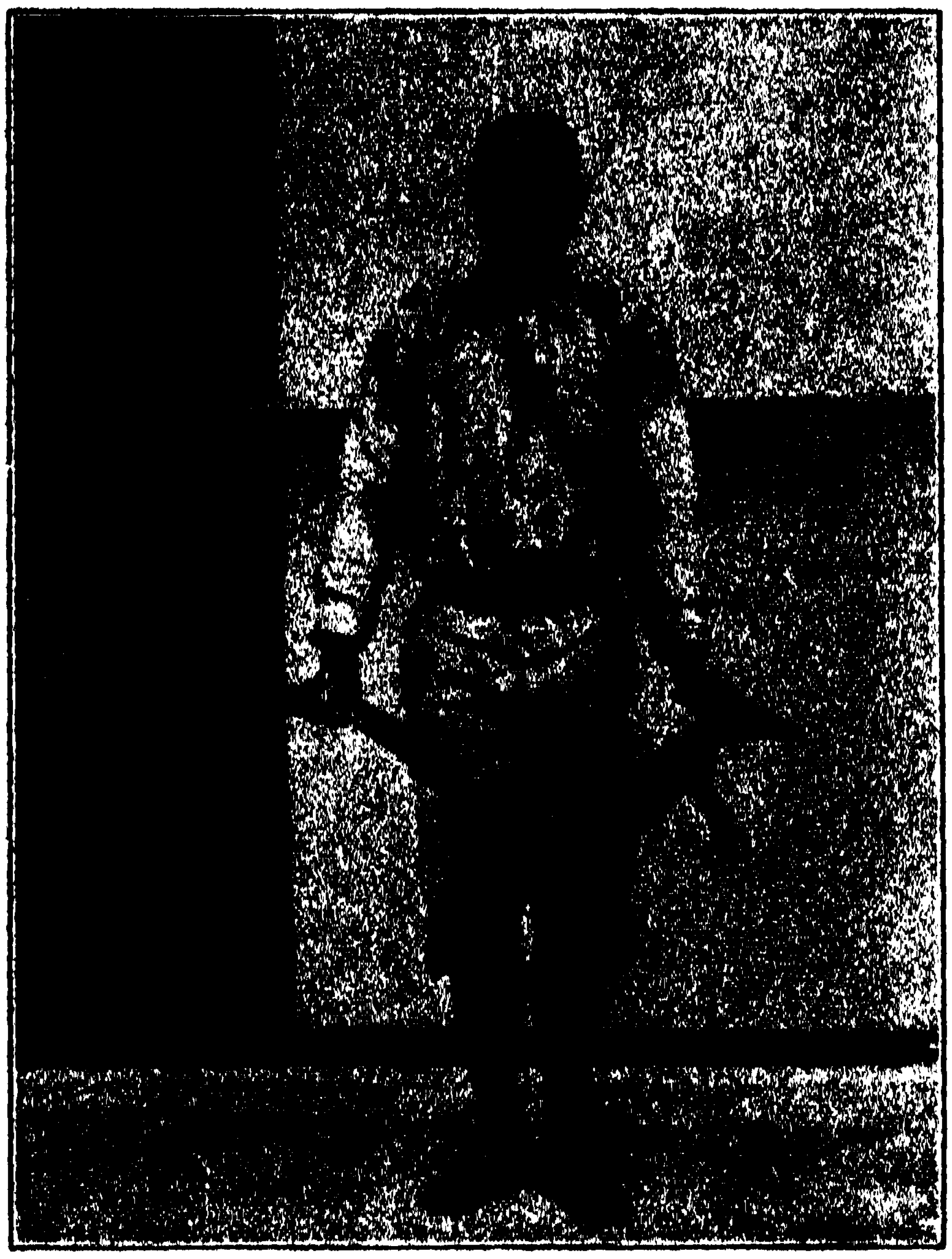
BOY CARRYING CASSAVA ROOTS



TERMITE MOUND

FOREST TERMITE NEST

Nigeria is to-day an undeveloped and in some respects a primitive country which promises rich commercial returns in the future. It still offers good game hunting and will probably continue to do so for some time, for great stretches north of the Niger receive little rain and will long remain scantily populated.



A MONITOR FORTY-SIX INCHES LONG

For the naturalist there is much of interest. In another paper the writer expects to give a short account of the native people of Nigeria.

THE EVOLUTION OF THE PARENT

By Dr. NATHAN MILLER

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THE original social relationship is that of mother and child. It is based on a deep-rooted organic foundation, which is the leverage point sustaining the whole edifice of the evolutionary process. This intimate physical bond recalls eons and millennia through which the spark of life that lay wallowing in primeval slime was nursed into the erect, dimly conscious mammal that writes articles about himself. The continuum of this epic process from the evolution of organisms into the social method of development is furnished by this same attachment of mother to child. The kernel of all succeeding social systems and relationships lies in the mother. The succession of generations of animals and the preservation of the species hinges on the maternal arrangement. Somewhat similarly, society with its heritages of tradition and experience takes its rise in this same bond.

There is no group that primitive which does not give evidence of the esteem with which the mother is surrounded. In the rudest and simplest of hordes there stands out a figure of the mother above the general vagueness of social outline. Even where the wife or woman is abjectly degraded in status, the mother is always recalled with deep expressions of sentiment. Livingstone was struck by this fact in the course of his explorations in Africa. In a moment of sudden terror or fright, the otherwise calloused native would cry out the name of his mother. All other social attachments were transitory and spasmodic. The struggle for existence was too ruthless and pressing. There were none of the "noble" sentiments that can be cultivated except that most patent and primal concern for and adoration of the mother.

The reasons are not far to seek. The physical attachment of the human child to his mother is long-protracted. Born very helpless and impotent, without the claws, teeth, fur or the keen senses of the animal, its existence is bound up irremediably with that of the mother. In the simpler societies, in addition, suckling is a long-continued affair. This is due to the lack of animal or plant food adapted to the infants' use. In fact, the child is often mature physically before the lactation period has ended. Among the Papuans, for example, Hagen on one occasion observed a small rascal run up to his father, snatch the cigarette from the father's lips, puff away and shortly thereafter resume his interrupted meal at his mother's breast. In the Bismarck Archipelago, similarly, youngsters of four years have been seen indulging in the same mixed diet.

The child must thus remain a veritable appendage to the mother through a longer course of years than we are accustomed to. When the mother is at work in the fields, the child is securely strapped to her back. Mother-love is quickened and more enduring and the child's existence is part of that of the mother's. Should she succumb during the child's early years, the child is buried with her. The natives of the D'Entrecasteaux Islands in Melanesia bury such a child alive at its mother's breast and stamp down the ground above it. Nothing else is possible where social structure is still inchoate.

Yet the native genius of all races has

idealized this attachment to the mother in endearing terms. As in all folk expression, the common life experiences of the group are colored and spontaneously expressed. Thus, among the Maoris of New Zealand the native poetic talent has drawn up this distich sung to the child:

My necklace of scented moss;
My necklace of fragrant ferns;
My necklace of odorous shrubs;
My sweet-smelling locket of Taramea.

The highest traits of the American Indian character were aroused, undoubtedly, in his relation to the child. The Chukchee of the Siberian wastes treats the child with great tenderness and uses the affectionate term of "little eggs" in common parlance.

However, maternity appears to be quite a trivial incident in the "lowlier" stages of societal development. There is very little hubbub or perturbation of expectancy and preparation surrounding the advent of the child. Usually the expectant mother is kept to her laborious stints up to the last days. At all times rationalizing justifications can be easily supplied for current practices, or mores. (This, even where foreign offices, official spokesmen and professional historians have not yet appeared.) So, according to Hooper, the Coahuila Indians of California believed it best "that the expectant mother have plenty of work to do during the nine months so that the child may be industrious and strong." Consider the Fijian woman who has been known to go out in the morning in an advanced stage of pregnancy and return in the evening with a load of firewood on her back and a newborn child in her arms. Nansen relates that on one of his journeys an Eskimo woman was overtaken with labor. The husband thereupon nonchalantly dozed off. When awakened he expressed his satisfaction "by smiling at his spouse and saying 'Ajungilatit' (Not so bad for you)."

The ruthless severity of nature is not, as yet, tempered or insulated by an economic and social system sufficiently developed and evolved. The individual struggle for existence annihilates in time of need and distress the budding social sentiments including this mother feeling. Infanticide — apparently a breach in the ways of a group—may yet become so usual as to amount to a common usage or folkway. Among the Kuni in Africa, infanticide is very common. "There is not a woman who has not killed one or several children. It is a cruel custom which all the women have to follow because, as they say in kuni, 'kufumai tsi koakoa doka' (such were the customs of our ancestors)." In the islands of the Torres Straits, in fact, the practice is arranged for before the birth of the child. The Polynesian women are known to do off with four, six or even eight children during their lifetime. The reason most often given in explanation of this is the shortage of food. Ellis says of the Polynesians that they are not willing to cultivate a little more ground or undertake the small additional labor necessary to support offspring during the helpless period of infancy.

Even when the child is spared it is open to intermittent bursts of cruelty and savagery upon the part of the parent. These are incited, again, by the exigencies of a harsh, bare environment which can not, as yet, develop the finer sentiments into a stable consistency. Personal vexation and animal discomfort caused by the child is often sufficient provocation for inciting the mother into violent action. Momentary impulses still rule. The Abipone mother may be accustomed to bewail the death of a child through disease, yet she does not hesitate to dash out its brains when food becomes scarce. The Australian mother in her bursts of affection "buries her face in the neck of the child and draws in a long breath through her nostrils: in fact, she smells it." But the bitter, sterile environment withers such sentiment. Even child cannibalism is often a horrible aftermath, as in Samoa, where Turner witnessed such an occurrence during a great scarcity caused by a gale. "If a child was seen out-of-doors someone would entice it by holding up something white and calling the child to get a bit of cocoanut kernel and so kidnap it . . ."

Intolerable outbursts of temper, alone, are sufficient to work this grievous result. As the rule there has not yet been any development of a system of discipline and punishments on these social levels. The children are accustomed to the utmost wilfulness and obduracy and given full rein in their conduct. Yet in a sudden streak of passion or vexation (as has been described of the Sandwich Islanders), a mother is liable to sacrifice the child on a trivial incitement. For example, some have done this simply to pique or retaliate against their mates.

Certainly the maternal sentiment, though deeply embedded, has an irregular mode of expression. The attachment is purely animal-like. This may account for its fitfulness. Extreme fondness is often displayed toward the young animals with whom the women may play for hours at a time. Many pertinent and well-substantiated cases are at hand to illustrate. To choose one: in Guiana, tame animals, particularly young apes, are the pride of the women. They are nursed and tended exactly as though they were children and become so attached to the women that they dog all their steps and movements. Like evidence comes to us with respect to the now-exterminated Tasmanians, the old Hawaiians, Patagonians, and others.

These facts are abhorrent and disagreeable to the sensitivities and sympathies of a "civilized" people who are supported by a developed, elaborated social system. The eulogizing of mother-love is, to be sure, token of the depths which this feeling plumbs, of the intimacies burned and seared indelibly into the blood and bone of the child of a highly "cultured" group. Nevertheless, in the ruder, simpler levels where the struggle for existence itself is bereft of the safeguards of a developed economy, sentiment can not survive stark reality. As long as food is plentiful the child has all latitude of freedom and has showered on it unbelievable indulgence and kindness. But where each individual must grub for himself the rôle of the mother becomes subordinated to that of the individual seeking to sustain life itself. Civilization has erected upon this foundation an economic and social superstructure, which is our "culture" and which has woven subtler bonds about the concept of the "mother." Custom has directed its expressions into longer-visioned ideals and deeper values or at least permitted of a more constant, wholesome expression of this eternal tie.

Turning now to an investigation of the development of the concept of the "father," we find a similar line of approach. Only here the connection of father with child can not be said to have that firm organic tie possessed by the mother. The bond is extremely tenuous, uncertain—and for long ages—an entirely misunderstood and problematical one. The notion of the male as procreator is extremely hazy and dubious, if not entirely lacking in the stock of ideas and their social manifestations among primitive groups. Nor is it to be wondered at. An adequate realization of paternity had to wait upon a large accumulation of experience and observation. Particularly was this evident in the earliest forms of society where children could be bound up only in a general way with the mother. All social organization as a result was extremely vague and disordered. Under the dominion of the natural appetites and urges there was little impetus to discriminate and select the male parent. The whole history of the development in establishing the definite, exclusive notion of the male parent was motivated probably by the necessity of bequeathing and endowing the children with the status and standards of life of the male parent. The nearer we approach the dim region of social origins, however, the closer we touch upon relative promiscuity. Under such conditions the idea of the male parent was naturally non-existent.

Among the most primitive groups of which we have reliable data the attention and interest of the older males is directed not to particular children in that intimate personal sense connoted in the term "father" to-day. Instead, the older males give sporadic care to the younger—alternating between extreme indulgence and frightfully barbaric cruelty. Indeed the child is a plaything and flatters his parent as a toy model. Primitive communalism reigns and parental oversight is carelessly diffused. The first clearly "social" division born of human association in groups was probably between generation-groups, old and young. Here the differences in muscular strength and power are obvious. The strict rôle of the parent is borne on these stages solely by the mother.

As the ideas surrounding the "father" develop, in some such fashion does social organization become elaborated and more settled. The first employment of the term was not to establish and describe the genetic connection of paternity but rather to express the economic status of the male as regards the young immediately about him. Now the male looms up as the preponderant contributor in the struggle for existence, as compared with the woman. In this gradual transition there has occurred the most significant, telling step in social evolution. The male eclipses the woman in the development of society primarily because of his superior economic contribution to the life which came in with the pastoral era. The domestication of animals fell uniquely upon the men and insensibly metamorphosed most social notions, including that of parentage.

This revolution occurred only in the nature of all social forces—slowly, lumbering and haltingly progressing. The effect was to render the man all-powerful and despotic and to thrust the woman into the status of a slave or chattel-dependent. The children as well fell into the position of property, and the "father" became a mode of expressing ownership rather than parentage. Thus, among the Ewe-speaking peoples in West Africa, neither of the words now used to express "father" bears any relation to the act of begetting. "They do not mean 'he who begets' but 'he who owns' and 'he who maintains.'" The native language contains the word "fofo," which is an older term for "father." It is derived from the verb "fo," "to support, maintain." Among the neighboring Yoruba the term "baba" means lord, master, great person or father. In East Africa, similarly, we have it on good authority that the owner of a woman is regarded as the owner and father of her children, whoever the real progenitor may be. In Siberia, also, the Yakuts had no name for "father" which admits of a natural and simple explanation, like the word for "mother." The word for "mother" means "procreatress," but the word for "father" should be translated "older man."

The climax of this line of development is reached in the full-blown patriarchy where the traditional patriarch or "over-father" stands with over-weening prestige, power of rule and ownership of women and children.

The narrowing down of the term "father" to the actual progenitor was the direct reflection of man's experience probably with the breeding of animals and the simultaneous growth of knowledge. We can not claim a continuous or exactly concurrent series of events in the development of social concepts throughout the world. We can state with some degree of certainty, however, that paternity is a notion of comparatively recent origin and the fruit of countless centuries of progress in the adjustment of men to life in society.

As society progresses, thus, to the attainment of the knowledge of the domestication of animals and plants, the male dominance grows. The older mother régime had never been tantamount to a system of rule by the women, as has often been asserted. There was never more than a vague adherence to a mythical original mother along with an apparent laxity in organization, absence of tabus and lack of differentiation of the individual in the usual concerns of life. Cohesion was about this actual or legendary female ancestor. With the advent of the patriarchal reign there arose a persistent motive toward social division and the creation of various levels or status in life. Invidious distinctions arose. Children acquired added worth and benefit to the father. Their economic contribution to this struggle for standards in group-life was magnified. So, also, does their value increase as caretakers of the departed parental ghosts which hover beseechingly and dangerously about the hearth. For such reasons it becomes of supreme importance to have children and to identify them irretrievably as one's own.

This truly social note is betrayed in many lands in the ceremonies whereby the "father" accepts, identifies or lays claim to his children. The exact form this assumes is queerly redolent of the traditional, more firmly established parental relationship—that of the mother. This is illustrative of the ordinary tendency in society of the ancient usages and beliefs to hang on tenaciously beyond the day of their effectiveness, borne along by the great weight of the customary and indifferent past of the group-life. The old never dies totally in society. Thus, the Rhodesian "father" ties a string of beads on the child's wrists and legs, and takes it and nurses it in his arms. In the Celebes Islands, the mode is more striking. There the father bites off the navel-string of the child to indicate approval of the child as his. In the D'Entrecasteaux Islands, the rapprochement between father and child (for such it may be called) takes place through the consumption of a common meal. This has always been a popular method of cementing relationships not eminently obvious in the nature of things. The father and the child sit down to a meal prepared particularly for them. Others may look on, but only these two may partake. It is quite evident that the mother never was moved to employ such typical ceremonial fictions to establish *her* relation to the child.

For many centuries the notion of parentage was thus a fragile, uncertain bond. The attachment to the child was preeminently fixed upon a physical basis. The deep tokens of affection bestowed on the child astound us even to-day, as among the most primitive of peoples—the Australians, the Veddahs, of Ceylon, the Ainu, of Japan, the Fuegians, etc. But all this is irregularly displayed indeed. Privation and want will mean the taking off of the child without the slightest compunction or hesitancy. Contrast with this state of affairs the elaborate and specialized organizations and provisions for the care and instruction of the child of to-day—care and solicitude that are the products of the anxious interest of the parent of to-day.

This striking contrast is explicable only in the light of the interpretation of social evolution set forward in the above. The child falls into a status and a position of dependence as the group life evolves out of its undiscriminating simplicity and acquires a body of tradition, lore, economic apparatus, tried ways of life and mores. In the early stages examined here the difference between parent and child, especially in the struggle for self-maintenance, was very insignificant. Young and old were alike "children of nature" and as such possessed equal ability to wrest support from the environment. The child left the maternal breast to be thrust directly into the business of life. There was no superior skill that the parent could impart save that of sheer force and brute strength which nature alone could provide. As time passed, the group slowly carried along with it increasingly effective folkways which cut a clear gulf between the parent and the child. In addition, ideals and traditionary experiences become the child's heritage and these are to be received through the parent. Otherwise they are lost forever. Hence there emerges insistent motives for training, discipline and an education that nature alone can not enforce without allowing each generation to start anew in its own way. The tremendous weight of tradition and the zealous, invidious interest of the parent place the child definitely in its position as the heir of the ages.

The mother concept and feeling is transfused and elaborated by this annexing of many-faceted social impulses to the bare urges of the organism. The stress toward equipping the child with the far-flung ideals of one's own station and ambitions in the social scheme reinforces the mother sentiment as described above. Certainly the "father" sinks more complex roots of interest in the child. The motives are very often, of course, of very selfish origin, as the child begins to reflect the wealth, titles, "honor" and worth of one's position in society or the flickering ambitions in the struggle for standards of living. The idea of the relation between parent and child deserves careful study in this light as it is coming to acquire vital and permanently changing significance in the great propulsive sweep of society. Today the suspicion is being voiced that the business of being a parent is fit subject for taking of stock and thorough discussion as the times—and the mores—change so rapidly. The only point at which to start may most profitably be some such examination of the past as here presented.

ARSENIC EATERS

By Professor NORMAN J. HARRAR
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ONE of the poisons known to the ancients, one of the weapons of many famous and of many more obscure criminals, one of the allies of man in his war on marauding insects, one of the most deadly of toxic substances—arsenic.

Perhaps it is because of this traditional association of death-dealing properties with the compounds of arsenic that makes all the more striking the contrast afforded by the peculiar habit indulged in by the people called "Arsenic Eaters."

References to this custom in recent publications are usually brief and are frequently obvious restatements of equally brief notations in earlier works. That arsenic eaters live in Styria and eat the poison to improve the complexion and the breathing is the extent to which the subject is discussed. The testimony of J. F. W. Johnston (1855), who bases his remarks on that of Dr. Von Tschudi (1851), and of Roscoe (1860) and perhaps of a few other observers, unnamed, seems to be the chief source for these meager statements. In some respects, the story seems to be assuming the proportions of a legend. Therefore, it is not surprising that doubts as to the existence of the custom should be expressed, and we find in "Chemical Pathology," by H. Gideon Wells (published 1920), the statement that "There is, however, reason to question the authenticity of the reputed tolerance of habitués to arsenic." By numerous experiments, mostly on dogs, investigators have reported that an arsenic tolerance even approaching the reputed doses of the arsenic eaters could not be reached. The obvious conclusion drawn, therefore, is that arsenic eaters do not exist.

References to the arsenic eaters always locate them in Styria, a province of Austria, with Graz as its largest city. Therefore, an inquiry was addressed to the professor of chemistry of the University of Graz. This was received by Professor Scrabal, who referred it to Dr. Fritz Pregl, of the Medicinisch-Chemisches Institut of the university, who is considered to be their best informed man upon the subject of arsenic eating. Dr. Pregl has most kindly endeavored to give a survey of the present situation, in addition to important historical data, and this information, coming from one who is considered an authority in the very place where the custom is said to be common, ought to carry considerable weight. As a result of this correspondence, the writer is able to give a fairly complete summary on this interesting subject and to present some details, not found in previous accounts.

The important and seemingly disputed question is as to whether or not arsenic eating is prevalent, in what we are pleased to call this civilized day and age. To quote Dr. Pregl's exact words in answer to a direct question on this point, "Die Gewohnheit des Arsenikessens ist auch in der Gegenwärtigen Zeit in Steiermark üblich," which translates, "The custom of arsenic eating is common even at the present time in Styria."

Having cleared the way somewhat with this statement, a note on the character of the country, of its industries and of its people is appropriate. The province of Styria is in southern postwar Austria, bounded on the south and west by the provinces of Cariniola, Carinthia and Saltzburg, on the north by Upper and Lower Austria and on the east by Hungary. The northern and western portions contain the rugged Styrian Alps, cut by rather narrow valleys of four rivers, the Enns, Mur, Drave and Save, all of which eventually flow into the Danube. Lower lands, but of a steep, hilly nature, are found in the southern corner of the province.

With such a topography, it is obvious that the land is not well adapted to agriculture on any large scale, and it never has been extensively used for this purpose. However, the mountains hide a mineral wealth, which has given the people an important industry for many centuries. Gold, silver, lead, iron, coal and other minerals have all contributed their share to this industrial prosperity, but by far the most important and steadiest output has been of iron. There is an interesting tradition among the miners of Styria, which illustrates the point.

When the barbarians from the regions north of the Danube drove the Romans from this province of Styria, then known as Noricum, the Genius of the Mountains, willing to do the conquerors a favor, appeared to them and said, "Take your choice: will you have gold mines for a year?—silver for twenty years?—or iron forever?" The wise ancestors of the Styrians, who had just begun to learn the true relative value of the precious metals, by ascertaining, practically, that their rude swords were an overmatch for all the wealth of the Romans, at once decided to accept iron forever.

The most extensive iron mines are located around the Erzberg (ore mountain) which is said to be literally a mountain of iron ore and ore of a remarkably high grade. In fact, the quality is such that its fame spread and created a demand for it far beyond the confines of the province. For centuries this region has been the source of over half of the iron used in Austrian domains. The more important foundries are to be found at Eisenerz, Vordernberg, Hieflau, Zeltweg, Trafaiach and Neuberg. It is in the treatment of these ores that arsenic makes its appearance, and it is very probable that the entire history and perhaps the origin of arsenic eating is closely related to this industry.

The smoke from these furnaces carries a considerable quantity of arsenic, from which As_2O_3 readily precipitates. In the former so-called Giftkanälen, or poison pipe, this white arsenic collected and because of its origin was referred to as Hüttenrauch, or smelter smoke. This name was commonly shortened to "Hidri" and sometimes another corruption, "Hydrach," was used in speaking of the substance. At regular intervals, it was necessary to clear these flues and this was done by workmen equipped "mit Hammer und Meissel." In order to more efficiently remove the valuable by-product from the smoke and to prevent more completely the spreading of an objectionable substance over the surrounding land, modern equipment provides one or more condensing chambers. It is not purposed here to go into further detail about the process, but the interested reader can find an excellent description in the "Dictionary of Applied Chemistry," by Sir Edward Thorpe. However, it is interesting to note that the workman employed in the removal of the arsenic from these condensing chambers of the modern plant must wear special clothing of leather and protect his mouth and nose with wet cloths. Even with these precautions it is said that only arsenic eaters can perform this task continually.

The principal market for the product has been for the making of arsenical glass and for its legitimate uses as a poison, but considerable amounts have always been deflected for the purpose of eating. Quantities of arsenic, despite the strictest regulations, still get into the hands of the peasants, and to make the situation more difficult to control, into the hands of itinerant peddlers, who carry on quite a lively, although secret, trade. To quote Dr. Pregl, "Nearly in every farmhouse, or in any case in every second, in upper Styria one finds more or less arsenic mixture." This is not always the property of the owner, but frequently belongs to his horseman, who keeps it in some secret place.

The trioxide of arsenic, As_2O_3, is the form in which the poison is most commonly eaten. However, there is a curious preference exhibited by very many arsenic eaters, apparently for purely superstitious reasons, for a so-called artificial yellow arsenic. This probably is due to the connection the custom has with iron smelting, for part of the condensed material does contain sulfur and has a yellow color. Yellow arsenic, by which term As_2S_3 is designated, is artificially made by melting together arsenic trioxide and elementary sulfur and this product is sold by the peddlers to satisfy the demand. Dr. Pregl reports that upon examining a large number of these preparations, he found at least 75 per cent. unaltered As_2O_3 in every one and that in some cases the mixtures contained as high as 92 per cent. As_2O_3. Therefore, the preparations are falsely named and the preference is a mere fancy upon the part of those who are thus deluded. However, a preference of this sort is certain to be well known to the peddlers and carefully played up to, for they know, as is shrewdly said, "um sich besser bezahlen zu lassen"—for it pays better to suit.

The amount of arsenic which constitutes the average dose and the amount which would be a maximum dose have been variously stated in the literature. Upon this point, which is a vital one to scientists interested in the subject, Dr. Pregl is rather reluctant to be specific, for several reasons. These might be summed up as follows. The habit must necessarily be of a secret nature in these days, the indulgers themselves make no attempt accurately to measure the amount they take and probably because of this, there is no general agreement as to what the exact quantities are. However, he does recall demonstrations given at a gathering of medical men some forty years ago, when real secrecy was not so necessary, in which those accustomed to the poison ate it, spread on bread, in quantities of at least 2–3 g. In fact, this method of receiving the arsenic is still the most common. With his knife, the arsenic eater cuts away from a larger piece that quantity which he estimates with his eye to be the right amount. From time to time, he gradually increases the quantity as nearly as he can estimate it in this crude fashion. Briefly, it is not the nicely calculated dosage being absorbed by the drug fiend, but rather a somewhat variable quantity which through custom has become a part of the daily diet.

The effects of arsenic eating have provoked considerable comment. It is said to improve breathing, to increase the endurance, to fatten the body, to improve the complexion and to lengthen the span of life. All these effects, except the last, seem to be easily discernible in Styria. To quote again, "the respiration and heart action are facilitated and the nutrition improved, the appearance is brightened and the hair of horses and of men made smooth and glossy."

Very striking indeed, are the results of a stopping of the regular administration of arsenic, "then the phenomenon takes place in the opposite way, horses and also men decline, respiration and heart action become difficult, the appearance fails and the hair becomes shedding and shaggy." Dr. Pregl states that he has had on very many occasions the opportunity to personally observe these facts.

A question which naturally arises is as to whether or not the continued indulgence in the eating of arsenic produces ill effects. Upon this point, some writers have stated that a chronic arsenic poisoning takes place, basing their assertions on experimental data. In the case of the people of Styria, it seems that, "even after ten years," no apparent bad effects are discernible. It might be that careful examinations at regular intervals, over a long period of time, upon an individual typical of the group, using known amounts of arsenic, would throw some light on this question. The secrecy under which the habit is indulged makes this procedure rather difficult. In this connection, it seems almost too hasty to draw conclusions about the condition of the true arsenic eaters based on comparatively brief tests on dogs or even men.

Another obvious question which presents itself is as to whether or not any sense of pleasure accompanies the habit. There is no doubt but that no immediate enjoyment, such as the agreeable effects produced by narcotics, is connected with the use of arsenic. However, here again, one is confronted with the possibilities of a habit practised from generation to generation for many centuries. Of course, once the habit has been adopted, a potent factor in its continuance is the intimate knowledge of the disagreeable effects a stopping of the dosage would inevitably produce.

An important reason for the persistency of the custom is its use with horses and so by the handlers of horses. The arsenic is ordinarily administered to the horses on their food, or sometimes placed in the mouth where it slowly dissolves. This very probably serves as an aid to their endurance and undoubtedly improves their wind for work on the steep slopes and gives them a glossy, well-nourished appearance, even after a hard day's work. The handlers who do not feed arsenic are certain to suffer by comparison. Especially is this true in cases where a new man is employed, who is unaware of the fact that his predecessor used arsenic continually, for then no matter how carefully he handles his horses, the symptoms noted above soon appear. A restoration of the arsenic to the diet is the only remedy. In such a situation, it may not even require the threats of an angry employer to decide the course of action.

Attempts to prevent arsenic from reaching the people and to discourage its uses are due in no small measure to the relation it bears to crime throughout the country. Practically all poisonings are done with arsenic and the trials hinge upon proof of its criminal administration. Pausing a moment to consider, it is obvious that the possibilities are unlimited and absolute certainty almost unattainable. Dr. Pregl states, "In a year, I have had to undertake and to pass judgment upon, in legal proceedings, more arsenic poisonings than in all Germany in ten years." The more important reasons for this condition are the ease of procuring the poison, for, if no other source is available, it may be obtained from the peddlers, and the veil of secrecy under which the custom and transfer of the arsenic is shrouded. Hardly less important factors are the intimate acquaintance the people have with the poison, the possibilities of accidental reception and the more or less doubtful value of even proving the presence of arsenic by post-mortem examination. All this tends to create a remarkably difficult situation to handle and it is interesting to speculate how a half dozen typical American criminal lawyers could manage to make convictions a lost art in Styria.

Lest a wrong impression of this country result from this account, it is well to quote Dr. Pregl again, "It is false to think that the larger part of the population of Styria indulge in the custom of arsenic eating." A great number of the people have, in the course of time, gradually dropped the habit, so that conditions are certainly not as bad as they once were. However, it is true that the custom still is "fairly widespread" among the horsemen. Nor should these people be too readily condemned, for perhaps many of the customs of our country, not even having the saving excuse of antiquity, seem to them to be just as queer and undesirable.

A final query is concerned with the origin of this unique custom. It is not easy to follow the trail back through the centuries, but one or two significant facts seem to stand out prominently. The habit has always been closely connected with the iron-smelting industry; the arsenic has been eaten with the food; it has been commonly given to the horses. Perhaps some observant peasant of the long ago noted an improved condition in horses grazing near an iron foundry and was led to investigate. It is a matter for speculation. The chance ways in which many of our healing herbs and of our most practical remedies were brought into use are equally obscure and the names of the discoverers are unknown. Arsenic eating has a long past—and the beginnings are lost "in der grauen Vorzeit."

METHODS IN THE STUDY OF DOMESTICATIONS

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It is a fond delusion of many to believe that ethnology, because it deals essentially with living peoples of the present time, can contribute little or nothing toward reconstructing the cultures and culture movements of the past. What I wish to demonstrate by a few practical examples from the chips of my workshop for the benefit of the younger generation is that it is possible to reconstruct by means of purely ethnological data and methods mental processes and culture phases of the past which can not be reached by historical or archeological methods. I choose my examples from the domestication of animals, because this is a subject of fundamental importance for the history of civilization and but little scrutinized and elucidated by ethnologists.

Our domestic animals can be studied from many different angles—zoological, anatomical, biological, economic, geographical, historical, archeological—and these various sciences have made many excellent contributions to our knowledge of the subject. It is obvious also that only by a combination of the results gained from so many different fields can a satisfactory solution of the problems be attained. Yet the most interesting question relating to our domestic animals has hardly been touched upon, and this is man's relation to them, or in other words the domestic animals from an ethnological point of view. What motives prompted primitive man to go to the trouble of domesticating animals and by what means and by what mental attitude was the primeval process of domestication brought about? To the layman the answer seems easy enough. We hear it almost daily and read it in our school-books that man keeps sheep for the sake of their wool, cows for their milk, chickens for their eggs, swine for the sake of flesh, etc. But all the material advantages which we now derive from domesticated animals are but the effect and result of prolonged activity in matters of domestication, and cause and effect can not be identical. Wild fowl, *e.g.*, do not propagate to a large extent, nor do they lay eggs in great numbers. The egg-laying habit of our chickens, to such an extent that it was of some economic advantage to man, was only developed after many hundreds or perhaps thousands of years of a gradual evolutionary process of domestication. When primitive man first adopted the wild fowl into his household, he could not foresee or anticipate any substantial benefit, no more than the alchemist of a thousand years ago could foresee that his alchemical lore would develop into the science of chemistry in the nineteenth century. Moreover, the utilitarian viewpoint is contradicted by plain observations of present-day conditions. There are, for instance, many tribes in southeastern Asia, Polynesia and Melanesia who keep chickens and have kept them for millenniums, but do not use their eggs or their flesh; there are other tribes among whom the pig is a sacred and sacrificial animal and is eaten but once a year in the solemn act of a religious ceremony. The Chinese have raised sheep and goats for thousands of years, but have never utilized their wool for making textiles for clothing. All East-Asiatic nations keep cows and buffalo, but never milk these and never consume animal milk. Primitive man is not rationalistic, but emotional, imaginative, impulsive, and it is in vain to look for rational motives in his first contact with the animal world.

Years ago I pointed out that Asia with its European annex is split into two well-defined and sharply contrasted economic camps, the boundary line running along the frontier of China and Tibet. All West-Asiatics, including the Indo-European nations, Semites and all nomad tribes of central Asia, have a highly developed dairy economy, and dairy products, such as milk, butter and cheese, form an important part of their daily sustenance. The entire East-Asiatic world, however, including the Chinese, Koreans, Japanese, Annamese, Siamese, Burmese, Malayans and many peoples of India, do not take animal milk for food and evince a deep-rooted aversion toward it. A Chinese looks upon a milk-drinker with the same dislike as we may feel toward people who subsist on monkeys, snakes and insects. The amazing feature, of course, is not the mere fact that East-Asiatics do abstain from milk, for the natives of the South Seas, Australia, America, etc., do or did the same simply for lack of milk-producing animals, but the point at issue is that the Chinese and their followers adhere to this negative practice despite an abundance of milk-furnishing beasts (they rear cows, buffalo, mares, donkeys, camels, sheep and goats) and despite a long and constant intercourse with neighboring milk-consuming peoples whose habits and mode of life were well known to them; yet they never acquired the habit of milk-drinking. Now what does this fact mean? In the first place it means that our consumption of milk can not be looked upon as a self-evident and spontaneous phenomenon for which it is usually taken, but that it is merely a matter of educated force of habit historically evolved. Objectively it is not natural at all. As "natural" as it appears to us in consequence of time-honored tradition and custom, so just as unnatural, abnormal and barbarous does it impress the Chinese and other nations of eastern Asia. Above all, however, these plain ethnological observations and considerations may lead us to distinguish two ancient culture periods in the early history of Asia which lie beyond all recorded history and archeological monuments. In the first period, which denotes the primary stage in the domestication of cattle, the milking faculty of the cow was unknown to man. The ox was exclusively the sacred animal trained in the service of agriculture solely for drawing the plough, and simultaneously he was the highest sacrifice to the gods of heaven. The invention of the plough and the wheeled cart, as well as the cultivation of cereals, are events closely affiliated with the domestication of cattle. This is the very point which the cultures of eastern Asia have in common with western Asia and Europe. In the second period, western Asia advanced to the stage of dairy economy; this was a slow and complex movement operative on the one hand in the producer, the animal, in which the productive power was gradually trained as the result of a domestication extending over millenniums; on the other hand, in the consumer, man, who just as gradually acquired the habit of taking to milk. This new development remained confined to the West, but it did not affect eastern Asia, and must therefore have taken place at a time when the East was definitely settled in its culture pattern and was no longer ready to absorb extraneous ideas. It bespeaks a lengthy prehistoric cultural development in the East independent of the West. I do not continue this discussion, as I merely wish to cite this case as an illustration of how ethnological methods may carry us into the remotest past and help us to discover and unravel ideas of which no record has been preserved.

The following case is still more instructive, as it will bear out some unexpected results in regard to the domestication of the cock and the pig. The first striking fact in their distribution is the parallel occurrence or non-occurrence of the two. Both pig and chicken are sedentary animals and consequently make their domicile only in sedentary, never in migratory communities. I say advisedly sedentary, not agricultural, because neither pig nor chicken bears any relation to the stage of agriculture and were introduced into the great agricultural civilizations of continental Asia from the more primitive, marginal or peripheral culture-sphere of southeastern Asia. In Tibet with its division into two social groups, an agricultural one in the fertile valleys and a migratory-pastoral one on the high plateaus, pig and chicken are found only among the farmers, but never among the nomads who raise cattle, horses and sheep. Throughout eastern Asia cock and hog are met with as parallel factors for reasons which will become clear after awhile. The sole exception is presented by ancient Japan which had only the cock, not the pig. In Formosa both cock and pig were found by the Chinese at the time of the discovery of the island in A. D. 605. In Polynesia the two occur everywhere, but the easternmost isle, Easter Island, reflects the same situation as Japan; it had chickens, but no pigs, and chickens were the only domestic animals encountered there. New Zealand had neither the pig nor the chicken. Such factors of geographical distribution are the result of historical events, and each case of this kind merits a special investigation.

Coming back to my previous proposition, I now wish to offer an explanation of the motives and circumstances which prompted the original phase of the domestication of these animals, and I shall explain briefly how I arrived at my idea.

A fundamental of culture in eastern Asia is divination. In this respect we have four distinct culture provinces which despite their difference of method share one important point inasmuch as divination is based on the bones of certain animals. Among several ancient and now extinct tribes inhabiting Korea and Manchuria there was a system of divination from the hoofs of cattle and horses and the bones of oxen. In central Asia divination was practiced from the shoulder blade of a sheep which was scorched over a fire, and from the cracks thus arising in the bone the future was predicted. In ancient China the carapace of a tortoise was utilized in a similar manner. The tortoise was regarded as a sacred animal imbued with a knowledge of the future. In 1899 a deposit of several thousand fragments of bones, chiefly tortoise shell, was discovered at Chang-te fu, Honan. These bones are engraved with inscriptions of a very archaic style, representing the earliest form of Chinese script we now possess, and were used for purposes of divination. The oracles and in some cases the answers were carved into the bones. We meet, *e.g.*, inscriptions such as these: "We consulted the oracle to ascertain whether the harvest will be abundant," or "The oracle was consulted, as we wish to know whether God will order a sufficient rainfall so that we may obtain an adequate food-supply," or "If we go a-hunting to-morrow, shall we capture any game?" Divination has always dominated the whole life of the Chinese from the cradle to the coffin, and no business was transacted, no marriage concluded, no burial undertaken, without consulting a fortune-teller. These ancient augurs formed a special profession, in their social position comparable to the lawyer of our society. In the same manner as the modern financier and captain of industry consults his lawyer on all important questions, so the Chinese did not make a step in the most trivial matters without asking a diviner's advice.

South of the Yangtse and widely diffused all over southeastern Asia we find from ancient times a complex system of divination based on the femora or thigh bones of a cock. Formerly it had a much wider geographical distribution than at present, and was found among the Yüe, a non-Chinese tribe which occupied what is at present the southern portion of Chekiang and the province of Fu-kien, and among the widely extended Miao group in southern China. We have numerous Chinese records of this form of divination ranging from 110 B. C. down to recent times. At present this system of chicken-bone divination is still flourishing among the Lolo, the Karen tribes of Upper Burma, the Ahom and other tribes of the Tai or Shan family, and the Palaung and other tribes of the Mon-Khmer stock. Among all these peoples the cock is a divine or sacred bird, a supernatural creature, a messenger of the gods endowed with the gift of prophecy, with a knowledge of the future and of good and evil. He plays a fundamental rôle in mythology, in tribal migration stories, in prayers and rituals. Among all these people chickens are not primarily kept for utilitarian purposes, and the eggs are hardly, if ever, consumed. The most primitive conditions still prevail there in regard to fowl-rearing, and it is a curious and corroborating coincidence that the same area, Upper Burma, had previously been claimed by naturalists and orientalists alike as the primeval center for the domestication of the cock. Thus it seems to me there are good reasons for concluding that it was the practice of cock divination which was instrumental or at least the principal agency in bringing about the domestication of the bird. The Palaung still capture the wild jungle fowl and cross it with the domestic breed. Eggs of jungle fowl are often brought from the jungle and set under the village hen. The pullets when large enough to look after themselves are sometimes carried to the jungle and there set at liberty. These people are perfectly aware of the relationship of the wild species to the domesticated variety, and the interbreeding of the two continues under their care. They keep cocks essentially as time-keepers and as sacred birds in divination. According to their traditions it was the captive jungle-cock who was first employed for this purpose. Chinese accounts give us the same information with reference to the Miao tribes.

There is a peculiar reason why the Palaung constantly take recourse to the jungle in order to replenish their domestic stock. The thigh bones of fowl have fine perforations, the foramina of the blood-vessels, and these play a prominent part in the procedure of divination. Fine needle-like bamboo splinters are inserted into the foramina and project at various angles from the sides of the bones; according to their position (whether slanting, straight, or upright) good or ill omens are decided. There are books illustrated with over one hundred diagrams of chicken bones with the splinters inserted and accompanied by an oracle in old Shan. In the wild jungle fowl and in domestic fowl bred from jungle stock there is a much greater variation in the position and number of the foramina than in the pure domestic stock. For this reason the bones of the jungle cock are deemed preferable for divination to those of the purely domestic breed. This whole process goes to show that the Palaung are actuated by no other motive than the desire to have the service of the bird's divinatory qualities and that any utilitarian viewpoint is alien to their thought. Unconsciously and involuntarily they have contributed to the improvement and eugenics of their domestic stock by rejuvenating it with the blood of the jungle fowl, but the sole motive was and is to obtain a bird of a superior degree as the messenger of divine will.

It is a curious coincidence that among the majority of the tribes under consideration, the pig is likewise enlisted for purposes of divination. Among the Karen, the pig is an important sacrificial animal, and its gall-bladder is examined for favorable omens. In their elaborate divination rituals cock and pig function simultaneously. A peculiar condition prevails among the Khasi who draw auguries by examining the lungs, liver, spleen and gall-bladder of a pig; if the liver is spotless and healthy, *e.g.*, the augury is good; if the reverse, it is bad. On the other hand, the Khasi also revere the cock, regarding him as a mediator between the deity and man, yet in opposition to all other tribes of the area they do not use the femora of the cock, but its entrails. Here evidently the basic ideas of the pig complex were grafted upon the ideas of the cock complex, and this example illustrates well that the two complexes are closely interrelated and cultural parallels, and that correlations and adjustments have taken place between the two. The same condition as among the Khasi prevails in Borneo, and traces and survivals of this whole complex go over the entire Malayan, Polynesian and Melanesian area.

Another interesting point is that those primitive tribes to whom cock and pig are essentially sacred animals of religious significance have never developed cock-fights and pig-fights—quite naturally, for such cruel sports are reserved for the so-called higher civilizations. Again, the coincidence is striking that wherever in southeastern Asia we meet cock-fights there are also pig-fights; the two, *e.g.*, occur together in ancient Camboja and ancient Java. Much has been written on cock-fights, but no one seems to have seen what it is all about. This institution has also grown out of a form of divination, save that it is a sophisticated and materialized offshoot of it. In the beginning it was not individuals who set their roosters to fight, but villages and communities entered into a contest against each other to decide the question of superiority by relying on divine judgment that would manifest itself in the prowess of their divine roosters.

I hope that this brief outline is sufficient to show that through intensive ethnological study the history of our domesticated animals can be disentangled and that we may hope in course of time to be able to reconstruct culture sequences and periods in well-defined areas for a number of domestications. Like numerous other culture traits, domestications have been evolved progressively on a line from the irrational to the rational, or to express it more guardedly in terms of relativity, from what we are inclined to regard as irrational to what we are wont to regard as rational. For the Palaung who abstains from eggs, but trusts in the efficacy of the chicken-bone oracle is just as rational and honest and sincere in his way as we are in maintaining chicken-farms and eating cold-storage eggs.

AQUICULTURE AND THE FUTURE OF THE WATERS

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No problem of civilized man seems likely to be more enduring than that of enlarging the means of subsistence to keep pace with the increase of his numbers and the growth of his requirements. The chemists and the physicists may some time show us how to manufacture proteins, carbohydrates, vitamins and other necessities from the atmosphere and a little dust. As yet, however, they have not done so. At any rate, sustenance and raiment are now derived from animals and plants growing in or on the cosmetic covering of the face of Mother Earth. The problem, as we seem to have it, then, is to make the best possible use of the available areas of that covering.

We are told that the surface of the earth is nearly three fourths water and about one fourth land. The smaller area that is land is subject to cultivation extensively, and its yield per unit area has been steadily increased, first by the physical labor of man, and, second, through the progressive application of the results of experience and a growing fund of knowledge. Both factors, the physical and the mental, have undoubtedly been applied to the task from the very beginnings of agriculture, but the latter factor, intelligent effort, let us say, has been subjected, especially in very recent times, to a remarkably effective stimulus through the development of modern science and the translation of its fruits and its methods into a system of guidance and control for practical agriculture. We have now added to a practice of agriculture a young but vigorous and growing science of agriculture. This science, or group of sciences, may be immature, but it has safely passed the age of adolescence and no one questions its ability to endure and to perform a service of constantly growing significance to human welfare.

The far greater areas that are water, like the lesser areas that are land, had first to go through a period of exploitation, but, unlike the latter, they have scarcely passed beyond that crude stage. There has been some application of manual labor and intelligence to increase of production through governmental agencies, and, in some instances, through personal enterprise (oyster farming is an apt example); but it can certainly be said that there exists now no practice of water-tillage comparable in any degree to that of recent soil-tillage, and, correspondingly, there is no worthy science of aquiculture. We may not love the word "aquiculture," but etymology, logic and usage offer no substitute.

It is not out of place to inquire as to the causes of the remarkable lag of aquiculture, as compared with agriculture, in practice and in science. In the first place, let it be admitted at once that the comparison of three to one in favor of water as composing the surface of the earth is to an extent misleading when applied to the question of the utilization of the areas. We have no reason to assume (and none to deny) that science can ever make the greater part of the broad seas actually productive beyond its primitive condition. The applications of practical aquiculture, so far as we can now see, are to shore waters, enclosed waters and

rivers. The open sea, however, does demand the attention of science for its problems of conservation and of intelligent control of exploitation, if for no other reason. But our question remains: What are the causes for the lack of development of aquiculture in those regions that are subject to control?

The principal cause I believe is this: The obvious obscurity (if such a paradox be allowable) of the conditions and results of experimentation when applied with reference to the productivity of water areas. The land farmer plants or fertilizes and day by day observes with satisfaction or disappointment the results of his effort and thought. The water farmer may plant and fertilize, but he sees nothing—nothing that he can intelligently interpret. Rule-of-thumb methods develop more quickly and successfully in agriculture than in aquiculture. It may be said that the conditions of the soil are also obscure and complex and that the land farmer does not actually see all the results of his experiments and that he can not fully and correctly interpret what he does observe. True enough: as we know, he soon reaches the limits of purely empirical experiment when he must pass the problem to the agencies and the implements of scientific research. The difference as regards aquiculture is that such a limit is reached almost at the beginning and before the infant industry can have attained a clearly articulate stage. The application of inductive science naturally develops most rapidly in a field alive with empirical science—a field, let us say, which has regularly yielded crops of recognized value, has engaged a considerable number of more or less thoughtful laborers, has demonstrated its responsiveness to intelligent effort and has conspicuously sprouted its problems. As an illustration of this fact, may we recall that one of the most vocal demands for the aid of science to aquiculture comes from the relatively highly developed industry of oyster culture? The oyster farmers have seen sufficient results accrue from their own practical experiments to conceive of the possibility of aid from those possessing greater technical knowledge and the command of scientific method.

A second cause of the relative lack of development of aquiculture as compared with agriculture is the difference in ownership or control of the areas involved. Private ownership of land not only stimulates personal effort for increase of productivity but also prompts the demand for outside aid, and even science bearing gifts is not scorned. To illustrate again, no demand for the service of science comes from the exploiters of public areas of oyster production, but only from those who have a vested interest in particular sections of the bottoms of coastal waters. I believe, however, that the slight development of private ownership of water areas is to a large extent a secondary cause and a result of the primary cause first mentioned. The lack of conception of possible gain proportionate to effort inhibited the assumption of control at times when private ownership of the surface of the earth was first coming into being.

With such causes at work in the past and the present, why will they not continue indefinitely in the future? The answer is—the development of science. Science will call forth the industry which did not rise up to cry for it. The development of the sciences necessary to promote aquiculture lies largely in the hands of those who are permitted to look into the future rather than to minister solely to the immediate demands of industrialists, in short, with the men and the agencies of science and with governments to such an extent as a more enlightened public policy may take cognizance of the need of attacking fundamental problems for service of the future.

To put in summary form the outline

comparison of the progress of agriculture and aquiculture and the probable future of the application of science to these industries:

With regard to agriculture, there was first an era of exploitation of public areas, then communal cultivation stimulated by the favorable results obviously obtained from the application of labor and thought; later the development of private ownership in most countries and application of empirical science, crude at first but progressive. Later agriculture becomes a private enterprise of the first rank among human occupations—the era of application of empirical science. There follows the birth of a science of agriculture in supplement to the efforts of private enterprise—such a science in this country dating practically, I presume, from the birth of the United States Department of Agriculture in 1862. There has ensued a further development of the science of agriculture stimulated by the definite consciousness of need on the part of agriculturists. In the future we may anticipate enduring vigor of agricultural science supported by a clientele eager for its aid and assured of its practical utility.

As regards aquiculture, we started with an era of exploitation of public areas and have progressed very little beyond that point. There was a limited development of private ownership and control in ancient times, as witness the fish cultural practices of the Romans and others of the older peoples. Aquiculture became a sporadic enterprise of secondary importance, with some development of empirical methods to increase production, chiefly in the growing of oysters and the cultivation of carp, tench, goldfish and trout. There has been a very slight development of a science of aquiculture beginning in this country, we might say, with the establishment of the United States Fish Commission in 1871. Its further development has been retarded by the lack of a responsive clientele of aquiculturists and perhaps by the actual distrust of many of the exploiters of public waters. For the future we may anticipate a more vigorous growth of aquicultural science, promoted primarily by a public consciousness of its importance to mankind.

This outline history points to two conclusions. The application of science to the utilization of water areas will arise not so much from the needs and demands of practical aquiculturists who seek to preserve and enlarge an accustomed livelihood as from the foresight and resolve of those whose vision encompasses its possibilities. Any extensive development of aquicultural practices will be the fruit of aquicultural science rather than the reverse.

If these conclusions are correct, we have anticipated one answer to a question which must arise some time in the minds of every one: Why concern ourselves with the need for utilization of water areas? Why not leave such problems to the sure working of economic laws which will apply the solution whenever the stringency becomes sufficiently tense? Now, the writer will frankly confess that, after a good many years of more or less vain argument in the cause of aquiculture, he found himself settling into the attitude represented by that question. We ought to make better use of water areas, he thought, but there is no need arguing about it. Leave it to time. When the pressure is sufficient. when the population can no longer find full sustenance from the land, the waters will come inevitably into their own. Out of this lethargic and fatalistic attitude he was shaken by three considerations. One was such a mental review of the history of the case as has been given above, from which it appeared that, however satisfactory economic laws might generally be, they would not work to a proper conclusion in this case. The second was a loss of faith, which is perhaps becoming somewhat general, in the certainty of operation of some so-called economic laws. If the pressure of need inevitably causes productiveness, then the most over-populated countries should have the most efficient systems of agriculture, and we should look to India and China for the highest development of agricultural science, and to all tropical countries with their wealth of disease carriers for the chief advances in medical science. Yet it is not so. Something else than economic need accounts for the growth of science. Something other than necessity mothers invention. If intelligence and enlightenment, or whatever it is that gives a people vision and resolve, that lifts them above the bondage of daily digging for physical sustenance, if such are the forces that fertilize the other sciences that promote human welfare, is it not upon these also that we must rely for the developments that we now have in mind? It is in no way expressive of doubt nor savoring of pessimism to assert that the future of aquicultural science is contingent, not upon the near approach of starvation, but rather upon the maturity of a conception among enlightened people that it is useful and worthy of the effort to produce it.

Now it was said that there were three factors which disturbed a formerly lethargic attitude. Perhaps chronologically the third, which has not yet been mentioned, worked first upon our convictions. It is this. We may leave to time the solution of our problem of the proper use of waters; but, while we serenely wait, the waters pass from us. The seas may be the embodiment of endurance, but the primarily productive areas of shore and tributary waters can be changed and are being changed in ways that diminish their productiveness. This is not the place for argument or for detailed data; but it is undeniable that the general trend is downward as regards practically all animate resources of the coastal regions and of the rivers and lakes of the interior. The writer has recently had occasion to look into the trend of the fisheries of the greatest of our river systems, and any one who does so will be astonished at the steadiness of the decline in the productiveness of the waters of the Mississippi basin during the past thirty years. We may speculate as to the causes, but the results are not obscure. Let us cite a particular incident that may be suggestive. Not many years ago a great dam was constructed across the Mississippi River. It may have checked the passage of a few fishes, but it provided broad flood areas for the production of food and for nurseries of young fish. In a few years there appeared a striking upward spurt of the local yields of some commercial fishes; very soon, however, it was held necessary to build levees and to put under land cultivation the best part of the breeding grounds of the fish, and a few more years saw the yields of the fishes for several of these species fall far down again. Here is a series of clearly established facts in chronological order, whatever may be the relations of cause and effect.

We may wonder what are the causes of the steadily diminishing importance of the fisheries of our chief river system. A decline noted during a period of a few years may not be significant, but, when the downward movement ensues without break during a period of thirty years, we have a trend that can not be viewed with complacency. We know there are causes at work, and we wonder if the causes and the results are inevitable.

We are confronted with two sets of problems. First, there are the special problems presented by each and every species of useful animal or plant of the waters. What are the conditions necessary for its perpetuation in maximum abundance? Problems of the cultivation or conservation of aquatic resources. Second, there are the problems of the preservation of the waters themselves. What are the conditions and practices that will best maintain the rivers, lakes and coastal waters in condition of maximum productiveness? And this last problem, simple as it may be in the stating, leads into an amazing complex of interrelations. The improvement of streams for navigation, the building of dams and treatment of the pools formed by them, the maintenance of shores of streams and lakes, the making of reservoirs for flood control, the formation of innumerable ponds for domestic uses, fish ponds and stock-watering ponds, the drainage of overflowed lands along great rivers and bordering the coasts, the disposal of sewage and industrial wastes, the ditching and tiling of agricultural land, deforestation and reforestation—these and other expressions of man's activity all have their bearings upon the productiveness of streams and lakes.

And the reciprocal relations of a proper policy of water conservation—its bearing upon flood control, navigation, forestry, agriculture and climate—these are of no less significance. There may be conflict of interests and a wise policy can be followed only by the sacrifice of one or the other; but there is reason to believe that the conflicts are not so great as might be supposed. The past attitude, according to which almost every case involving waters is presumed to be decided without consideration of aquatic resources, is clearly wrong. There is evidence to indicate that the sacrifice of water conservation entails in the long run a sacrifice of the resources of the land. I seriously doubt if there is any substantial conflict between the causes of aquiculture, flood control, navigation, forestry and agriculture. In any event, the ultimate policy with reference to land and waters must be based upon a broad view of the whole problem in all its bearings and with the fullest possible information regarding the conditions and relations of each sphere of interest.

In this very hasty review of a subject large in its significance and complex in its relations, we have sought to develop three chief points. Let us recall them. First, there is strong need for more extensive and intensive application of science to the problems of the conditions of life in waters, both for the possibilities of improving productivity and for the regulation of the use and exploitation of the waters under conditions of natural productivity. Second, the utilization of waters and the relevant studies have lagged far behind the utilization of land and the application of science to its problems; but the lag has been due not to lack of need or potentiality so much as to the difference between the two cases as regards the conditions of practical experimentation. The land yields to rule-of-thumb methods more generously than the water, which reserves the secrets of its productivity from the rough experimenter. From this follows our third and concluding thesis. The natural order of development of practice and science in the field of aquiculture will be the reverse of that which has prevailed in respect to agriculture. Instead of finding a well-developed and vigorous industry to call science to its aid, we must in this case start mainly from the scientific end and let science to a great extent generate the industry which will require its guidance.

We do not at all mean to imply that this is a unique instance of the necessity for a creative function on the part of science. It is, however, a case where progress is more purely dependent upon that function than in other cases of the basic industries. Modern science is young, but growing in influence, power and responsibility. More and more in the future will it serve to create industrial practices and public policies. We believe we are citing a particular instance where creative effort on some part is called for, and we have no doubt that in the end it will be the stimulus and the guidance of science which shall lead us to make the fullest response to the primeval command: "Let the waters bring forth abundantly the moving creature that hath life."

VOCAL THERMOMETERS

By BERT E. HOLMES

In common with nearly everyone brought up in the country, I learned, when quite young, that crickets do not chirp when the temperature approaches the freezing point. But not until the fall of 1923, when my attention was directed to the matter by an office associate,[1] did I suspect that a definite and measurable relationship exists between the rate at which crickets chirp and the prevailing temperature. Having sensed the possibility of the existence of this relationship, I immediately began making observations and have since made them whenever possible. During the falls of the four years 1923–'26, I made about one hundred and thirty-five. These observations prove that a remarkably close relationship does exist between the rate of chirping and the prevailing temperature. Also, they yield a formula which explains the relationship.

This formula is expressed below in two ways: first, as a simple and practical rule which one can use when experimenting with this interesting phenomenon, without the aid of pencil and paper; and second, as an expression developed by means of refined mathematical methods. The latter, of course, also can be used for the purpose of experimenting, but its use demands more time and pains than are required when the simpler rule is employed.

The simpler rule is: "The prevailing temperature (degrees Fahrenheit) equals the number of chirps made in 15 seconds, plus 37." One can try out this rule merely by counting the number of chirps made in a quarter of a minute, mentally adding 37 to the count, and then comparing the result with the temperature as shown by a thermometer. On the average, the difference between the calculated and actual temperatures ought not to be greater than one degree.

The formula as derived mathematically, by the method of least squares, is: "The prevailing temperature equals 258 one-thousandths of the number of chirps made in one minute, plus 36.9." By using this formula and taking greater care when making observations, one will get more accurate results than can be obtained by means of the other rule. It is well to count the chirps for at least two minutes, and then to calculate the average per minute, carrying the result to one decimal place if necessary. The thermometer reading should be made as accurately as possible, preferably to fractions of a degree.

The upper section of the accompanying diagram shows the formula expressed as a straight line. This line starts at the left edge at about temperature 37° and rises as it proceeds toward the right edge of the diagram. It will be seen that this line rises about 1° for every four chirps per minute that it moves to the right—just as the cricket makes about four chirps more per minute for each degree which the temperature rises.

Each dot or circle which appears on the diagram represents an observation. For example, the dot "A," which appears near the upper right corner of the diagram, shows that when a particular observation was made, the temperature was 74° and the cricket was chirping 143 times per minute. And so on. See how close to the formula line nearly all of the dots and circles are. They hover around it during its entire length. This

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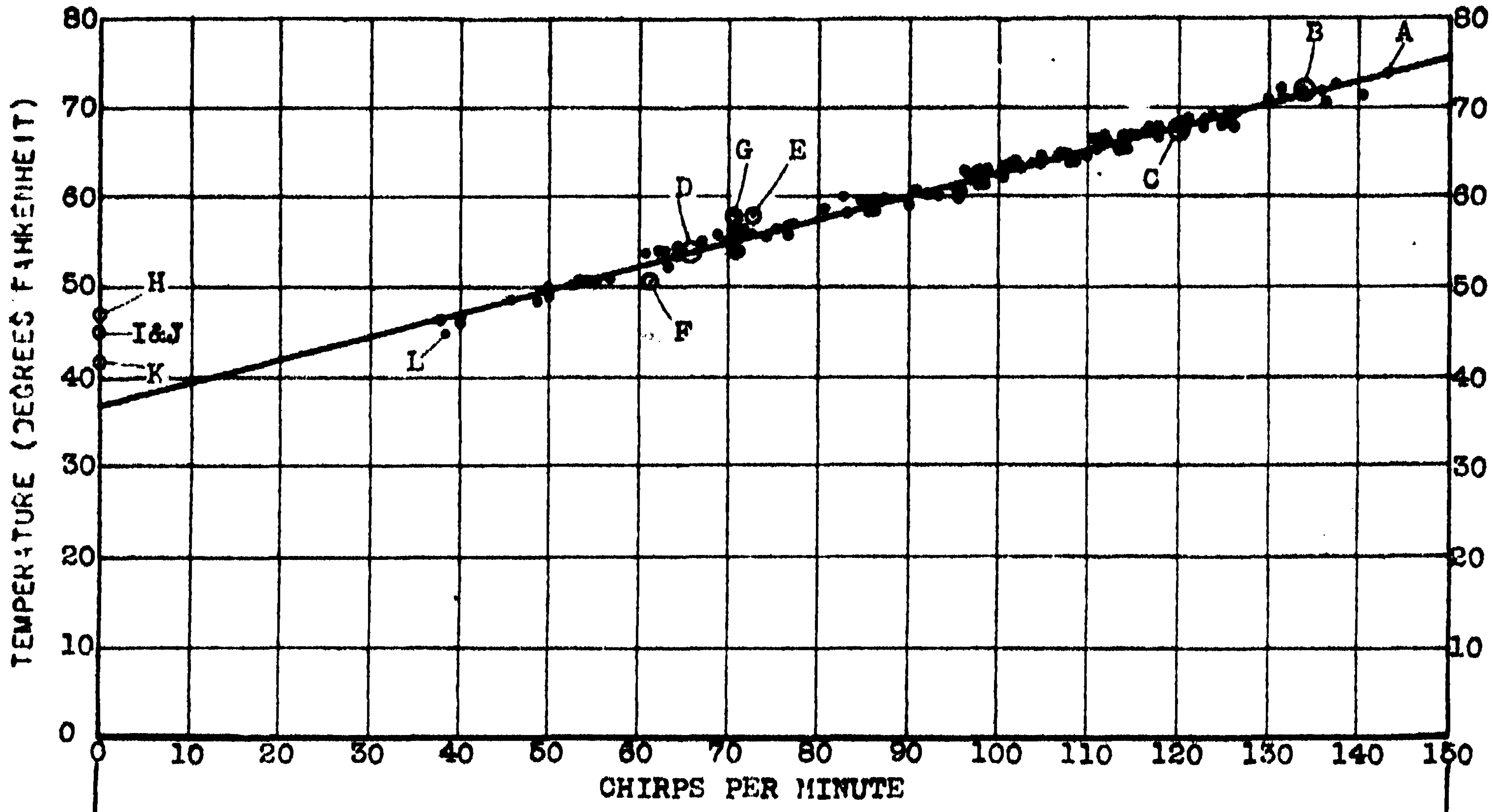
[1] Mr. Edward J. Hunt, New Haven, Conn.

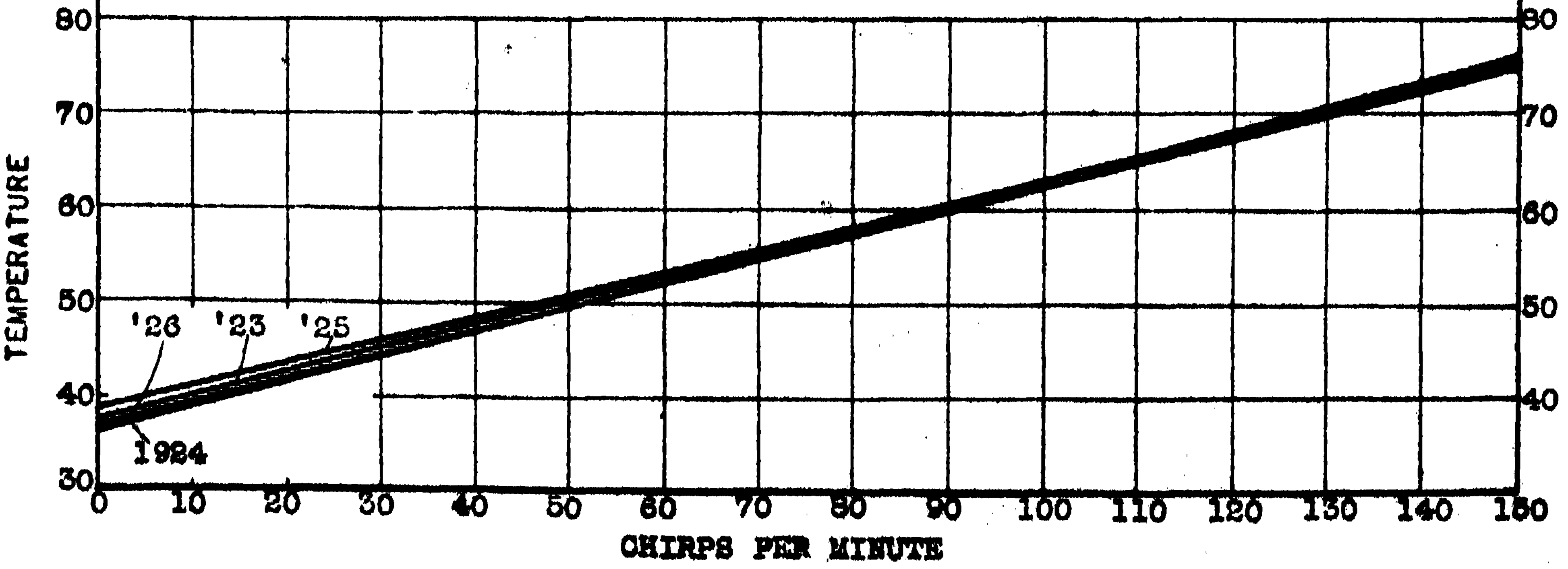


The line around which the dots cluster represents the relationship which exists between the rate at which crickets chirp and the temperature. Each dot or circle represents an observation, being located at the intersection of the chirps-per-minute and the temperature lines. For example, the dot "A", which appears near the upper right corner of the diagram, shows that when a particular observation was made, the temperature was 74° and the cricket was chirping 143 times per minute. Note how the chirps per minute increase as the temperature rises.

B Observed at New Milford) These three observations, which are practi-
C. " " " ")cally on the formula line, were made fifty
D " " Kent)miles inland from New Haven, where the others were made.

E. Observed Oct. 7, 1924) These three, the only ones whose dots fall
F. " Sep. 30, 1926)more than 2° from the formula line, were all
G. " Oct. 6, 1926)taken near the end of the season.

H. 47 degrees; no chirps) The chirping stops at about 45°, only one
I. 45 " ; " ")observation (L) having been made at this temper-
J. 45 " ; " ")ature and none having been made below it. Be-
K. 42 " ; " ")tween 45° and 47° three observations were made.



Here are shown the formula lines for the individual years 1923, 1924, 1925 and 1926. Note how little they vary.

association illustrates the remarkably close relationship which exists between the temperature and the rate of chirping—a relationship which holds over a range of about 30° in temperature, or from the summer temperature of 75° or so which prevails when the first cricket peeps, down to that—about 45°—which signals the arrival of fall and puts an end to the chirping.

How close to the formula line are the dots? Well, there are 115 of them, of which:

52, or 45%, are within ½ of 1 degree of the formula line
34, or 30%, lie between ½ degree and 1 degree of this line
20, or 17%, lie between 1 degree and 1½ degrees
6, or 5%, lie between 1½ degrees and 2 degrees
3, or 3%, are more than 2 degrees distant from the line.

Another way of saying this is:

52, or 45%, of all the dots are within ½ of 1 degree of the formula line
86, or 75%, are within 1 degree
106, or 92%, are within 1½ degrees
112, or 97%, are within 2 degrees
115, or 100%, are within 2.97 (greatest deviation = 2.96).

Although 135 observations were made, only 115 were considered in connection with development of the formula. Of the 20 whose results were not used, the greater number were made under conditions affecting their reliability—crickets were at a considerable distance and therefore hard to hear; or were chirping intermittently, as they do in the relatively low temperatures which obtain near the ends of seasons. In the remaining cases, although readings of temperature were taken, there were no crickets chirping. The value of these latter observations lies in the fact that they tend to show at what temperature the chirping ceases. A few of the temperature readings which were recorded when no chirps were being sounded are shown at the left edge of the upper section of the diagram. These will be referred to again.

For a time, I suspected that significant deviations from the formula line might be due to excessive moisture in the air, this causing the crickets either to speed up or to slow down. This is not so. Crickets will continue to chirp during a drizzling rainstorm. In fact, they are stopped by only a reasonably heavy shower. When they are forced to stop because of rain, they very frequently quit for the evening, even though the latter part of the evening be clear—but as long as they chirp at all, they chirp at the standard rate for the prevailing temperature.

Some of the deviations from the regular rates of chirping doubtless are due to differences between individual crickets; but the principal cause of fluctuations in rates is, I believe, differences between the conditions under which the chirps are made. Upon one occasion, the cricket under consideration may be beneath a stone or pavement which has retained heat obtained from the sun; while, again, he may be out in the open air in the pathway of a breeze.

The third footnote refers to the temperature at which the chirping ceases. This point is in the neighborhood of 45°, no consistent chirping having been observed at temperatures lower than this. As will be noted by reference to the footnote, twice, when temperature readings of 45° were taken, no chirps were being made. In numerous instances, when temperature readings of from 30° to 40° were taken, no chirps were being sounded.

The lower section of the diagram carries four formula lines, one for each of the years 1923 to 1926 inclusive. These formulas follow:

For 1923, the temperature equals .254 times the chirps per minute, plus 37.7. This is based upon 21 observations.

For 1924, the temperature equals .265 times the chirps per minute, plus 36.3. This is based upon 23 observations.

For 1925, the temperature equals .243 times the chirps per minute, plus 38.8. This is based upon 37 observations.

For 1926, the temperature equals .252 times the chirps per minute, plus 37.0. This is based upon 34 observations.

In a number of instances, the making of a satisfactory observation was a time-consuming process which required up to nearly a half hour's painstaking attention. Regularly, interference was caused by radios, by the rumbling of trolleys and by autos whizzing along nearby streets. At times, the sounds made by insects other than crickets tended to drown out the one note desired.

It is strange that although during the fall I invariably was able to find crickets by the dozen during the day, it was only upon most infrequent occasions that I could hear more than one or two chirping in the evening. Upon one occasion, when there were two, chirping at very slightly different rates, the resulting overlapping so hindered me in my attempts to obtain a correct count that I found it necessary to disturb one of the vociferous chirpers slightly in order to have him remain silent while I completed the observation.

During the first week of June, 1925, we had some almost unbearably hot weather. The newspapers regularly kept us informed as to how many decades had passed since we had been visited by an equally hot June 2nd, 3rd, etc. Toward the end of the week, or on June 5th, I heard a cricket. In so far as I know, I never before heard one in June. Had it been prematurely hastened into being by the unseasonable weather, I wondered; and what would he do? Well, for two days he faintly and intermittently proclaimed that he was alive, and then he stopped. I heard not another chirp for about six weeks. Oddly enough, one lone faint peeper made himself heard late in May during 1926. For just one evening he chirped in a hit-or-miss sort of way. Then—not another chirp until early August.

I have noted two kinds of chirps. Those usually made are the well-known shrill ones, which are regularly sounded, in many cases for the greater part of an evening. The others are hardly more than little squeaks, and are often made for very short intervals of time, and in unison with a series of the regular sounds. It is as though a young, inexperienced cricket were trying to keep pace with an older and practiced one. If this is the case, the attempts are successful, as the two sets of sounds synchronize perfectly, as a rule, as long as the little cheeps are made; but an "attempt" often consists of but a half dozen, and seldom of more than twenty, squeaks.

As the season draws to a close, and the chirps are made more slowly, it becomes clear that what earlier in the season seemed to be one continuous sound is in reality three or four very short sounds linked closely together.

Here is a wonderfully interesting phenomenon! These little creatures, the crickets, are with us for nearly two months during the late summer and early fall of each year; meanwhile chirping practically every evening, in places innumerable. And the frequency with which all of the resulting chirps are made is controlled by something outside of the crickets themselves! "Why?" one asks. But the answer to this question, like the answers to the other interesting questions regarding the subject which crowd into the mind, must await the results of further investigation and study.

AMERICAN WILD HORSES[1]

By Dr. JAMES W. GIDLEY

U. S. NATIONAL MUSEUM

THE domestic horse may be found to-day in almost all parts of the civilized world. From a time even before the dawn of recorded human history he has been a factor in the daily life of mankind and has occupied a vitally important place in the development of modern civilization. This long and useful association has endeared him to man, making him for many the favorite among our domestic animals. And rightly so, for without him the high standard of development which to-day marks human progress towards higher civilization would have been impossible. Before the days of the steam engine and the railways the horse was man's chief means of getting from place to place and was the chief source of power for land traffic of all kinds; he was indispensable to the early pioneers in seeking out and developing new territories for the habitations of man. And even since the advent of the railways, within the memory of most of us grown-ups, horses and horse-drawn vehicles have been most important auxiliaries to the railways for land transportation, and not so long ago furnished about our only means for joy-riding on Sundays and holidays. The usefulness of the horse in war has been praised in song and story from time immemorial, and for many hundreds of years he has been the chief reliance of the farmer in tilling the soil and harvesting his crops.

But the invention and development of the automobile and motor truck is changing all this; and to-day the scope of usefulness of the horse is being increasingly narrowed. He has almost disappeared from the streets of our cities and the main highways of the country, and is now confined principally to the farm, the ranch and undeveloped outlying districts which have not been reached by the railroads or graded highways.

The horse is also still much employed in the equipment and movements of modern armies, but not to the same extent as formerly. In the field of sport, only, the horse seems to be holding his own to-day. Here he is still king; and it is here perhaps he has reached the acme of physical development, as seen in the various strains of blooded "racers" and "hunters." In this connection it may be noted that these aristocrats of the turf, as well as the various breeds of great draft horses, the Shetland pony and all other distinctive varieties of domestic horses, are the products of selective breeding intelligently directed by man over a very long period of time; and also that they all were originally derived from only a few kinds of wild horses which once were native of certain localities of the Old World, including northern Africa, Arabia and Mongolia.

Thus the word horse became a household word many centuries ago and such it has remained, but to-day it is generally applied to the domestic breeds only. However, the naturalist's conception of the term is a vastly wider one and includes not only the living asses and zebras of the Old World, which are very near relatives of the domestic horse, but a very large number of kinds which in-

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[1] One of the Smithsonian series of radio talks arranged by Mr. Austin H. Clark and given from Station WRC, Washington.

RESTORATION OF EQUUS SCOTTI GIDLEY,
ONE OF THE AMERICAN HORSES OF THE PLEISTOCENE OR GLACIAL PERIOD. THE SMALL FIGURE IS EOHIPPUS INSERTED TO SHOW THE RELATIVE SIZE.

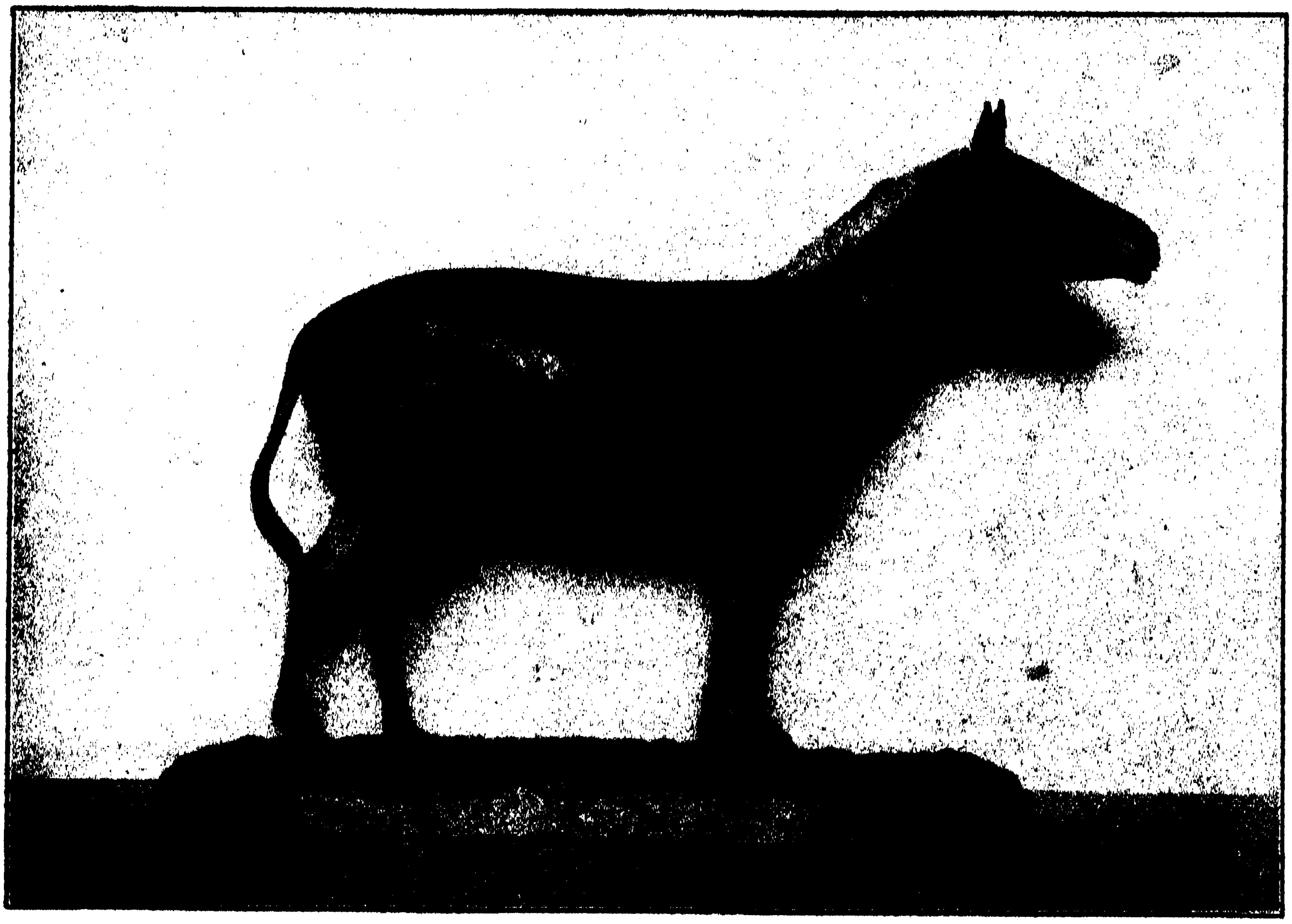
habited the earth long ages before the earliest human records were written.

The geologic records show that these earlier horses were far more numerous and diversified in kind than the horses of to-day, and going backward in time they are seen to be less and less like their living successors, although they all possess certain characters of body structure that stamp them as belonging to the same natural group of animals.

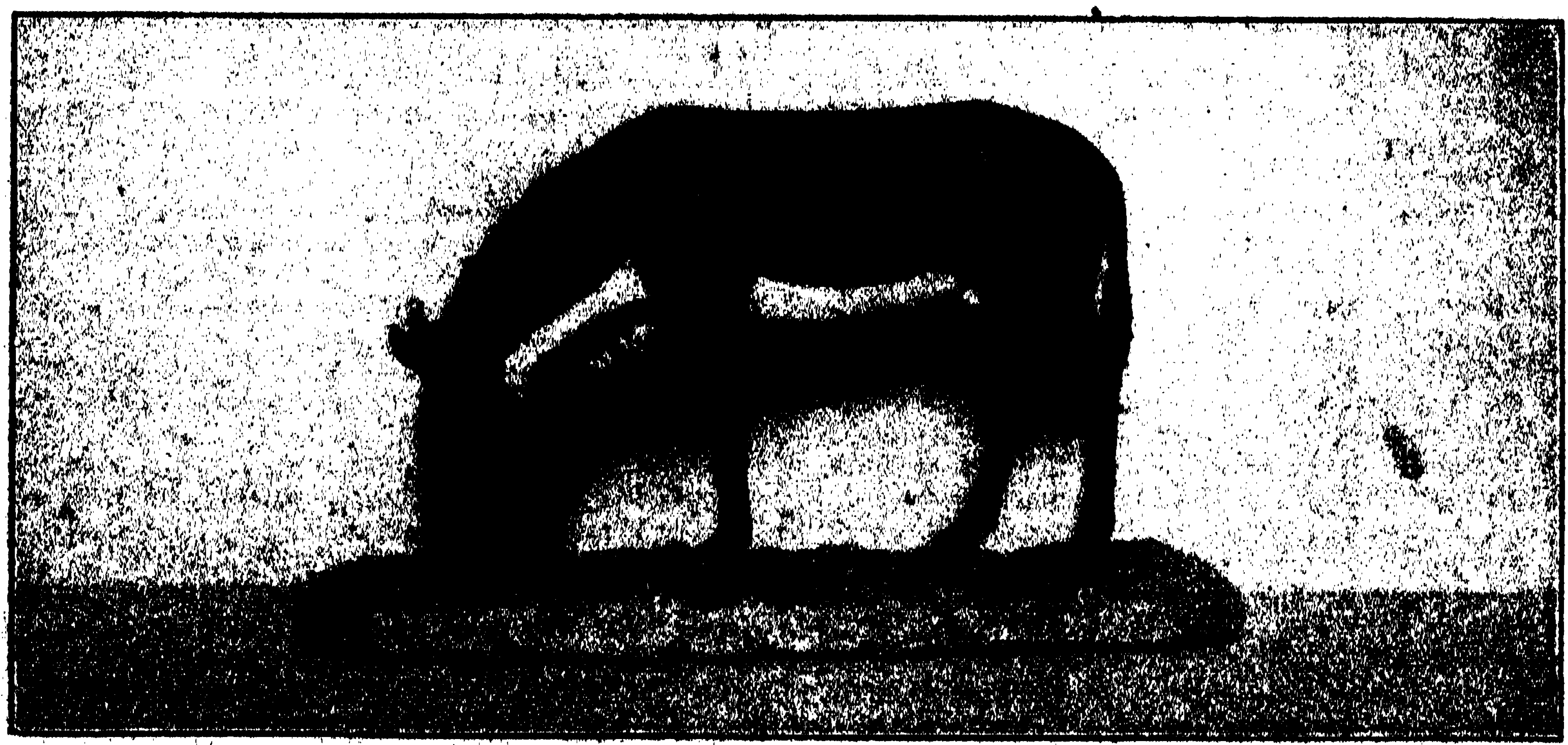
These older or prehistoric members of the horse family may quite appropriately be called the "ancient wild horses" and it is about that part of their history which belongs to America I wish especially to speak.

Nature has been most generous in storing and preserving, in the various rocks and earth-formations of past ages, the fossil remains of these early horses. In consequence their history may be read with an unusual degree of accuracy. Of most of the important kinds many skulls and skeletons are known; so that our reconstructions of body structure, whenever attempted, and studies of relationships are based on sufficiently adequate and abundant observed facts to make them reliable; and they in no true sense can be called the products of guesswork, as sometimes has been falsely remarked.

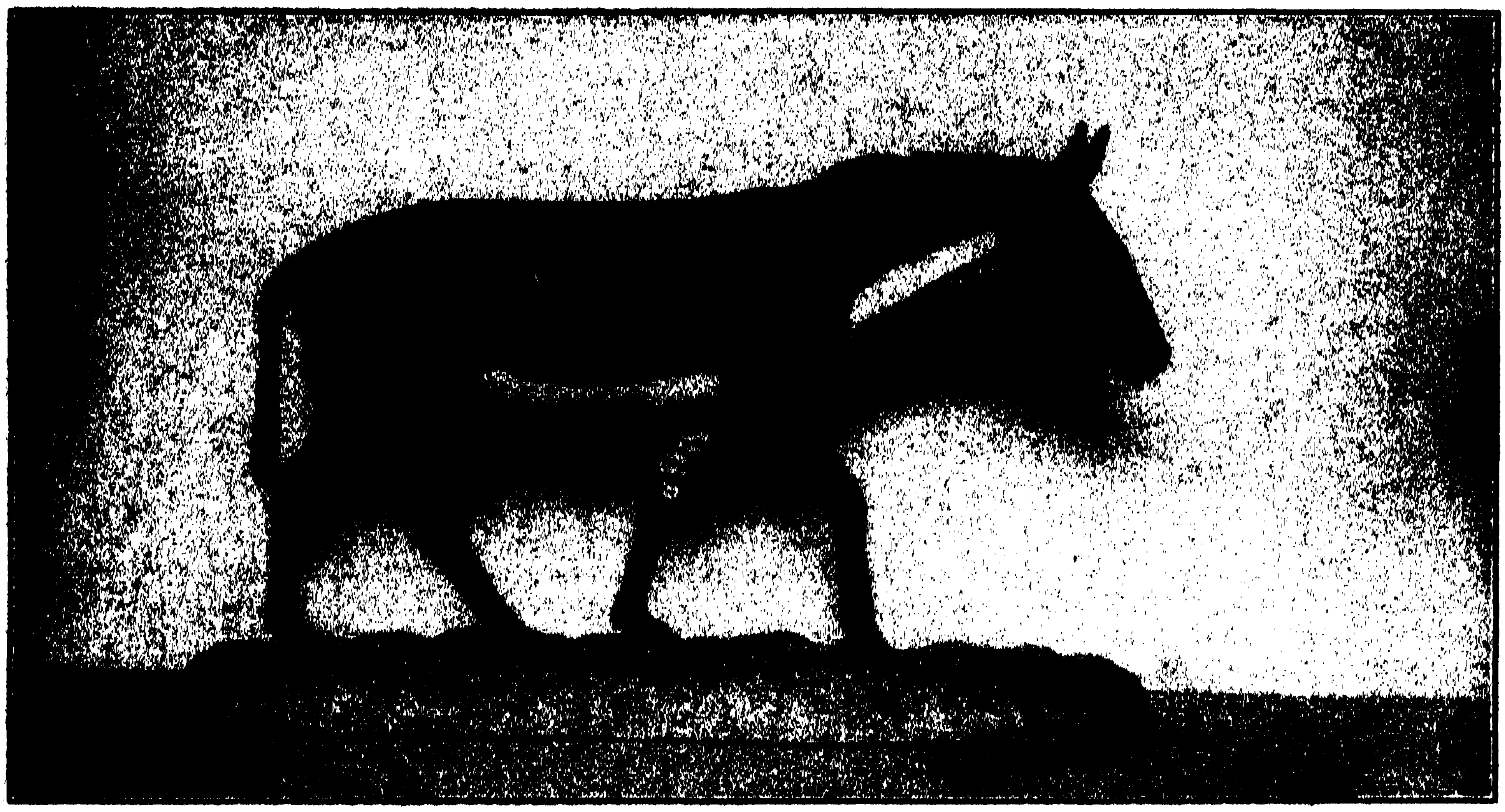
At the time of the discovery of America and its exploration by the early Spaniards, this continent is thought to have had no native horses. Be that as it may, in the prehistoric period just preceding our own time, known as the Pleistocene or so-called "Ice Age," true horses of many varieties roamed in great numbers over most of the American



RESTORATION OF NEOHIPPARION WHITNEYI GIDLEY,
ONE OF THE THREE-TOED HORSES OF THE BEGINNING OF THE PLIOCENE, REPRESENTING A STAGE IN WHICH THE LATERAL TOES WERE PRESENT BUT DID NOT REACH THE GROUND.



RESTORATION OF MERYCHIPPUS SEJUNCTUS COPE,
ONE OF THE THREE-TOED HORSES OF THE MIOCENE IN WHICH THE LATERAL TOES REACHED THE GROUND AND IN WHICH THE TEETH WERE OF THE HIGH CROWNED TYPE, THOUGH RELATIVELY NOT MUCH HEIGHTENED.



RESTORATION OF HYPOHIPPUS OSBORNI GIDLEY,
ONE OF THE ABERRANT THREE-TOED HORSES IN WHICH THE LATERAL TOES WERE WELL DEVELOPED AND THE TEETH WERE OF THE TYPICAL LOW CROWNED TYPE.

continents, both North and South; and their fossil remains have been found in all parts of the United States, in Mexico, Central and South America, and far north in Alaska even beyond the Arctic Circle. The horses of this period were all modern in type, and in life differed little or not at all in general appearance from the horses of to-day, but each kind possessed certain features which, to the naturalist, marked them as distinct from their living relatives and from each other. Like the living horses they were relatively long-limbed with a single toe and hoof on each foot, and their skulls were long-muzzled with deep jaws to accommodate the long high-crowned teeth so characteristic of the modern horse. In size they ranged from little animals no bigger than the smallest Shetland pony to kinds that excelled the largest draft horse. The period of existence of these horses extended over many thousands of years and as a group they seemed to have been very well fitted to continue on the American continent. Why they did not is an unsolved problem.

But this is by no means all the story of the wild horses in America. These horses of the Pleistocene were preceded by others of a still earlier geologic time. The fossil records of the later portion of the so-called Tertiary period, known as the Miocene and Pliocene epochs, give abundant evidence of earlier groups of horses even more varied in types and numerous in kinds than their successors of the Pleistocene just described.

The duration of this period was relatively very long, being measured by hundreds of thousands or perhaps millions of years, and the records show that horses were abundant from its beginning to its close.

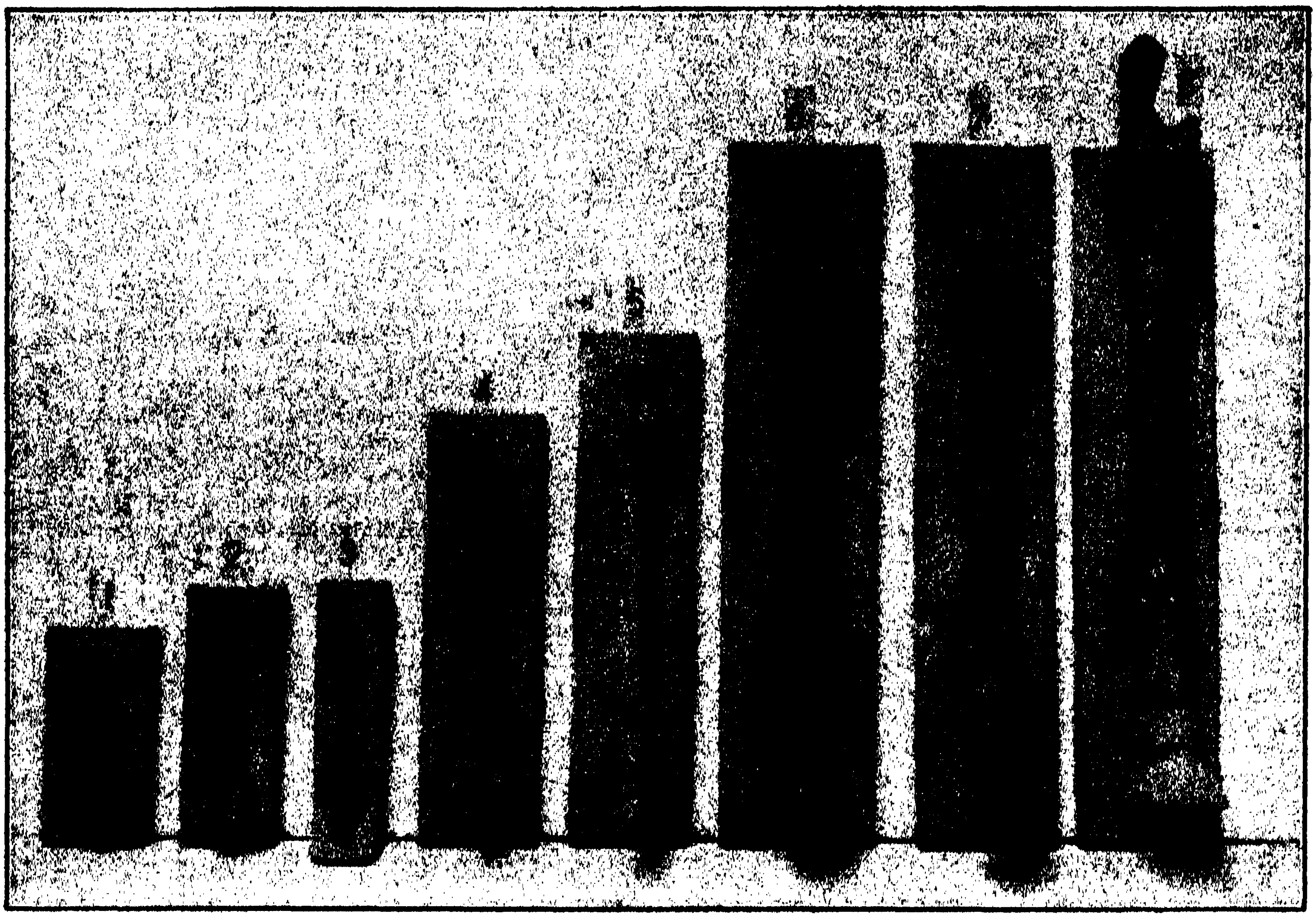
There were no very large horses at this time, and the general average size of all was notably smaller than that of their successors. Like their successors they all resembled modern horses in a general way, but most of them presented somewhat more noticeable differences. Most of them in fact differed in several rather inconspicuous but very important characters. These differences are especially observable in the structure of the

RESTORATION OF MESOHIPPUS BAIRDI LEIDY,
A TYPICAL THREE-TOED HORSE OF THE OLIGOCENE HAVING THE LATERAL TOES REACHING THE GROUND AND THE JAWS SHALLOW WITH THE LOW CROWNED TYPE OF TEETH.

feet and skulls. The limbs and feet of the horses of this period were much like those of modern horses, but in addition to the single, rounded hoof most of them had on each foot a pair of extra toes, one on each side of the main toe. These extra toes varied in size from small ones, resembling the dew-claws of a deer or elk, which did not reach the ground, to larger ones which reached the ground and must have borne some of the weight of the animal in walking. A very few kinds of this period had feet like the modern horses; that is, entirely without the lateral toes, but their remains have been found only in the upper or late section of this great time period. It is a noteworthy fact that most of the horses of the earlier phases of this period have longer and better developed lateral toes than those of the middle and later phases.

All horses with single toes, both modern and extinct, have a pair of long splint-bones on each foot, which lie closely appressed one on each side of the main toe. These do not appear on the surface, as in life they are covered by the skin. The upper ends of each of these bones are greatly expanded and have well-developed articular faces for contact with the small bones of the wrists and ankles. It is important to note that in the three-toed horses this part of the

RESTORATION OF EOHIPPUS INDEX COPE,
THE "DAWN HORSE," WITH FOUR TOES ON THE FORE FEET AND WITH A RELATIVELY SMALL SHORT MUZZLED HEAD.



HIND FEET OF DIFFERENT TYPES OF HORSES AND HORSE-LIKE CREATURES
1. EOHIPPUS (EOCENE). 2. OROHIPPUS (EOCENE; IN THIS CREATURE THE FORE FEET HAD FOUR TOES). 3. MESOHIPPUS (OLIGOCENE). 4. MERYCHIPPUS (MIOCENE). 5. HYPOHIPPUS (MIOCENE). 6. HIPPARION (PLIOCENE). 7. EQUUS (PLEISTOCENE). 8. EQUUS (RECENT).

foot is identical in structure with that of the one-toed kinds of horses, and that they differ in foot structure only in the presence in one and the absence in the other of the terminal three bones of the lateral toes.

In the skull structure of these animals, the principal differences to be noted are that the muzzle portion is usually relatively shorter than in the modern horse and the jaws are not quite so deep, due to a difference in relative height of the crowns of the cheek-teeth. In the Pleistocene and modern horses all the cheek-teeth when fully formed have long nearly straight crowns three to four inches or more in height. These are set deeply in the jaws and move outward as they are worn away by use. It is this type of tooth which gives the great depth to the jaws of modern horses. In most of the horses of the later Tertiary the cheek-teeth are of this type, but the crowns are less heightened and are usually much more curved. Both these factors tend to decrease the depth of the jaws.

A few kinds of horses of this period had teeth of a simpler type, in which the crowns are low and are attached to the jaws by means of roots. These kinds are for the most part found in the earlier phases of the period. It is also true that, of the kinds which have the high-crowned type of teeth, those with least heightened crowns are likewise found in the earlier part of this time period. And this group of the earlier horses represent in a way a transition stage between the strictly low-crowned tooth types, and the horses with the high-crowned types of teeth. For the young, or colts, of these kinds had cheek-teeth of the low-crowned type, which in adult life were replaced by teeth of the high-crowned type.

Referring again to the geologic records we find that in the next older epoch of the Tertiary period, known as the Oligocene, which in itself covered many thousands of years, still other kinds or species of horses inhabited the American continent. These more ancient relatives were smaller on the average than those of the next later period just described. Most of them were about the size of a shepherd dog or a little larger. A few were somewhat smaller. There were many kinds of these little horses and they were widespread in their geographic range, their remains having been found in many places in the west, in Canada and even in Florida. All were three-toed types with the lateral toes reaching the ground, and all had the low-crowned type of teeth and except for their smaller size must have closely resembled those of similar type, already mentioned, belonging to the next later period.

But even these are not the earliest known relatives of the horse. For all through the sedimentary rocks of the earliest epoch of the Tertiary, the epoch known as the Eocene or "dawn time," there are records of an abundance of little creatures much resembling those of the Oligocene, just described, only still more diminutive in size. They also had a main central toe with a well-developed lateral pair on each hind foot, but the fore feet were provided with four toes in place of three. There were slight differences, too, in the skull structure of these Eocene horses. These consist in technical differences of the teeth, important only to the naturalist and in modifications of the muzzle portion of the skull, which was relatively shorter than in the horses of later ages; so that the position of the eyes was about midway between the ears and the tip of the nose instead of being placed back nearer the ears as in later horses.

Thus we come to the oldest member of the four-toed group, which is also the oldest known member of the great group to which all horses belong. He was a little creature no bigger than a fox, and he has been very appropriately called *Eohippus,* a name which means "dawn-horse."

No known members of the horse family have five complete toes, but some of these little four-toed ones have in the foot an extra, small bone of splint-like shape that can only be interpreted as meaning that their ancestors, none of which have yet been found, had the full complement of five toes, the primitive number for all back-boned animals.

IRON CRYSTALS

By Dr. L. W. McKEEHAN

THE BELL TELEPHONE LABORATORIES

THE technical staff of the Bell Telephone Laboratories is always on the lookout for new materials and new methods which give promise either of better efficiency in telephone apparatus or of better insight into the physical behavior of materials already in extensive use. The recent announcements by English, Japanese and German investigators that single crystals of iron possess peculiar magnetic properties were therefore of special interest to the men responsible for improving the magnetic elements of telephonic equipment. One of the most striking of the newly reported facts is that magnetic hysteresis losses in single-crystal iron may be much lower than in "magnetic" iron of the usual commercial sort, which has approximately five million crystals per cubic centimeter. Since hysteresis is so fundamental in any explanation of ferromagnetism and is so embarrassing on its own account, interest in large iron crystals is natural enough. This interest has already resulted in the discovery of a new way of "growing" iron crystals for, at least, experimental purposes.

The crystals here dealt with would not have been recognized as such a few years ago, for it is only since X-ray methods were applied to elucidating the structure of metals that it became clear that the atoms in the grains of the metallurgist are arranged regularly in the geometric ways which give rise in transparent substances to the optically recognizable crystals first studied. Metal crystals very rarely have boundaries which indicate this structure and, naturally, never do when the process of making the metal has required them to be in contact with each other and formed their exposed surfaces in predetermined positions.

The reason why iron crystals must be artificially cultivated is, of course, that they do not grow wild. Some fairly extensive crystals which are mostly iron occur in silicon steel sheet as prepared for magnetic purposes and in a few other cases crystals big enough to work with have been found in the upper parts of huge steel ingots. Such haphazard crystals are not of the right shape for easy magnetic examination and in using them there is always the fear that the act of making them the right shape has played hob with the magnetic properties to be studied.

A straightforward way of tackling the job is to take a piece of iron of preferred size and shape and to form one crystal from the many which actually compose it. There are two ways of doing this, one being old and the other being the new method referred to above. The old way is due originally to Professor Albert Sauveur of Harvard University. The details depend upon the experimenter, but the essentials are: (1) that the iron be annealed so as to give it a nearly uniform grain-size, with grains not too coarse and not too irregular in shape; (2) that the piece be over-strained, not too much nor too little; and (3) that the temperature be raised slowly enough and high enough so that one grain (perhaps not one of those originally present) will grow so large as to occupy the whole of the strained portion. The control of the various steps is not easy and even when

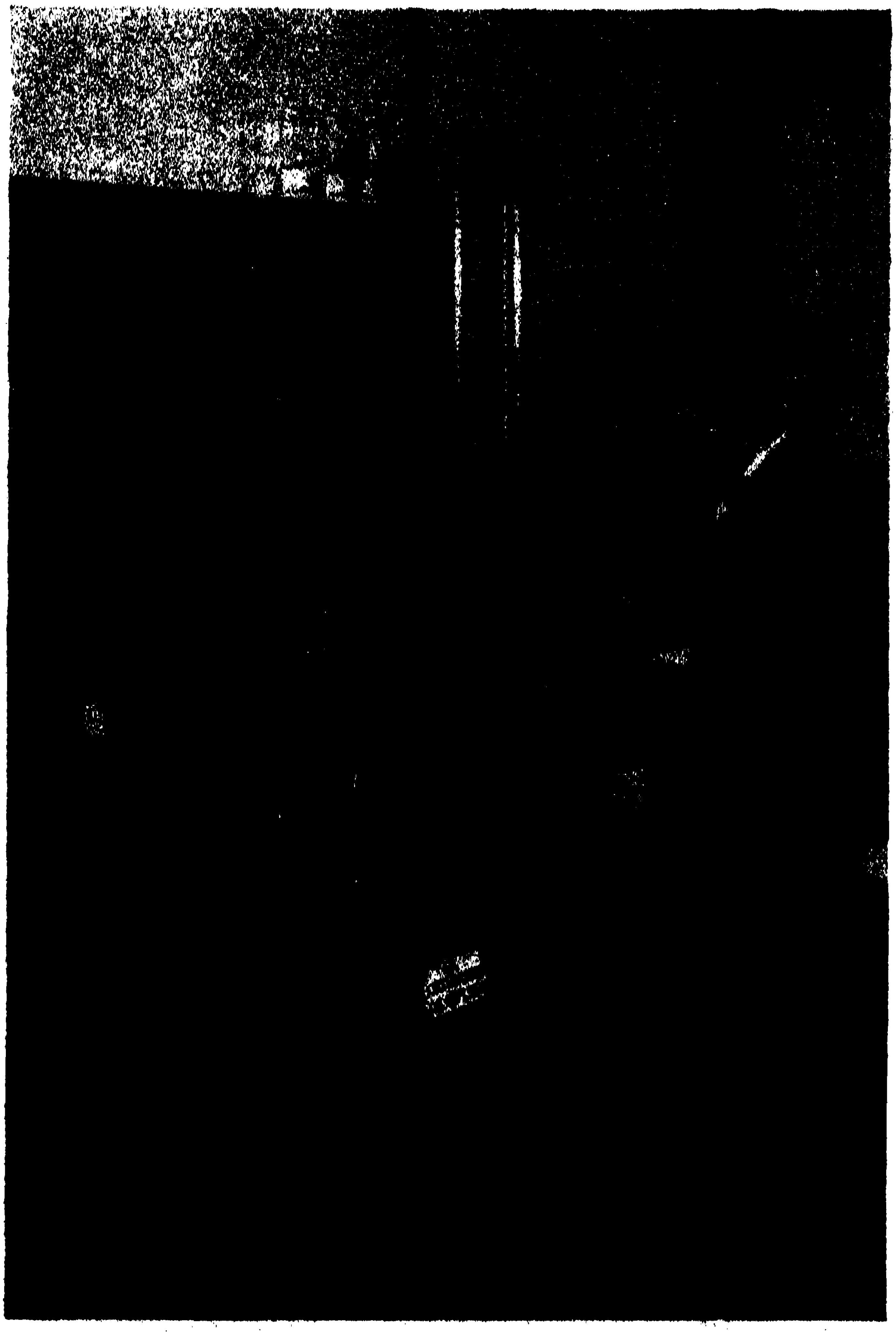


FIG. 1.—APPARATUS FOR CONVERTING IRON WIRE INTO A SINGLE CRYSTAL. THE OPERATOR IS EXAMINING A SINGLE CRYSTAL GROWN IN THE APPARATUS IN FRONT OF HIM. THE WIRE TO BE CRYSTALLIZED IS HELD VERTICALLY IN THE APPARATUS AND THE SOURCE OF HEAT WITH ITS ASSOCIATED APPARATUS IS CARRIED BY A REVOLVING SCREW ALONG THE LENGTH OF THE WIRE.

the greatest care is taken the experimenters report that failures outnumber successes.

The new way was devised by the writer. The essentials are: (1) that the iron be heated much above 900° C; and (2) that it be cooled progressively and not too fast in such a way that at every moment the part cooling through 900° C is a very thin layer in a region of steep temperature gradient. These conditions are met by moving a hot spot steadily along a vertically supported rod or wire. In the latest design of apparatus the heating is provided by an electric current carried by the millimeter wire in which the crystal is to appear. The contacts through which the heating current enters and leaves the piece are rigidly connected and are carried by a lead-

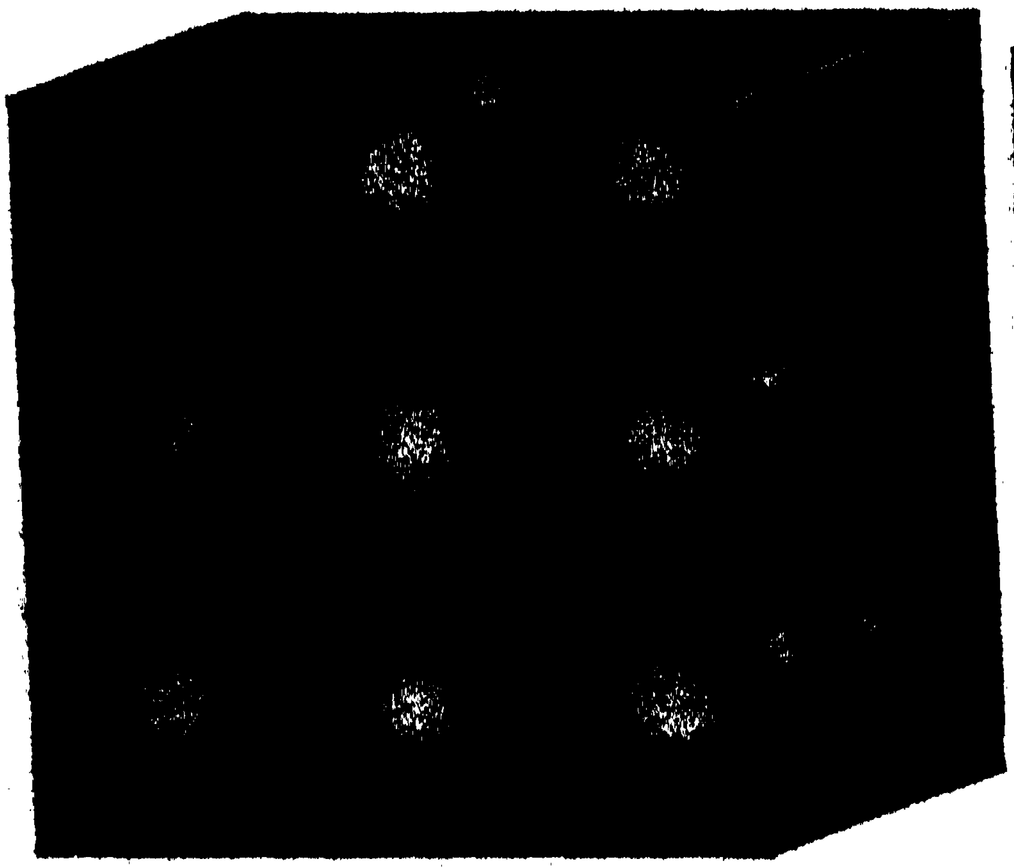


FIG. 2.—THE ARRANGEMENT OF ATOMS IN γ-IRON, THE FORM STABLE ABOVE 900 DEGREES CENTIGRADE. THE FACES OF THE CUBE SHOWN ARE OF THE CRYSTALLOGRAPHIC FORM {100}.

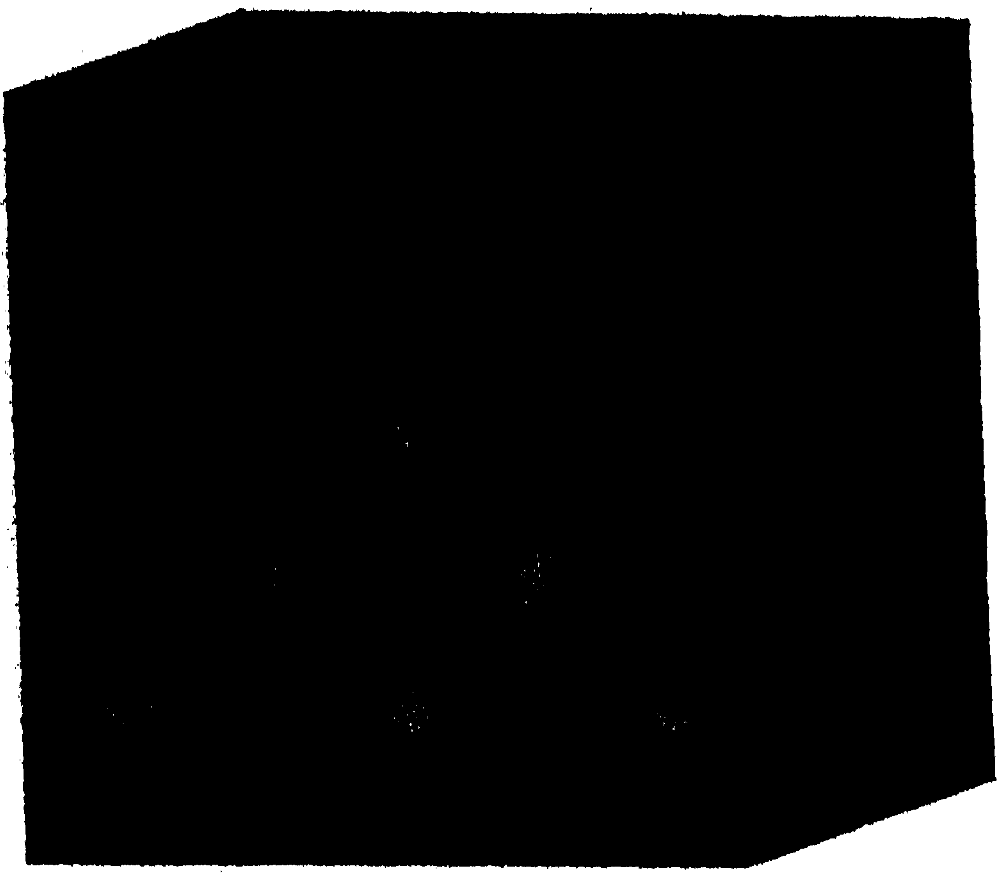


FIG. 3.—THE ARRANGEMENT OF ATOMS IN α-IRON, THE FORM STABLE BELOW 900 DEGREES CENTIGRADE. THE FACES OF THE CUBE SHOWN ARE OF THE CRYSTALLOGRAPHIC FORM {100}.

screw like that of a lathe. Since the hot part of the wire is weak mechanically and reactive chemically, it must be specially protected against mechanical and chemical reagents.

We think we know why these two ways work. In the old method the second operation leaves the metal principally composed of strained crystals which are at every temperature less stable than unstrained crystals. If then a bit of unstrained crystal exists, as is almost certain to be the case, it will at some stage of heating begin to grow by taking over atoms from the strained crystals in its neighborhood and rearranging them to suit its own structure. It can go on growing until it has rearranged all the atoms in the piece or until it meets another growing crystal over which it has no advantage. In this competition similarity of the original grains, the exact degree of over-strain and the rate of heating all affect the probability that one crystal may make a clean sweep.

The new method works because iron has two crystal structures, one stable above about 900° C, the other stable at lower temperatures. The former is called γ-iron and has a face-centered cubic-structure, the latter α-iron, a body-centered cubic structure. One structure starts to change into the other as soon as the temperature of the piece drops below the transformation temperature. If then a crystal of α-iron exists on the cold side of the 900° layer it can grow by taking up atoms as fast as they are supplied to it by γ-crystals on the hot side of the moving boundary. Since the volume within which steady conditions are important is smaller in the new method, it is not surprising that success in it is less dependent upon the purity and previous history of the iron. We find, for instance, that the carbon content does not have to be kept so low and that previous annealing is unnecessary.

Our experimental troubles arise from the mechanical and chemical weakness already mentioned. Small forces steadily applied may cause serious bending and side-slipping in the γ-crystal region, and while the α-crystal often grows right through these imperfections the irregular shape which results makes it impossible to apply the same magnetic and mechanical forces to every part of the

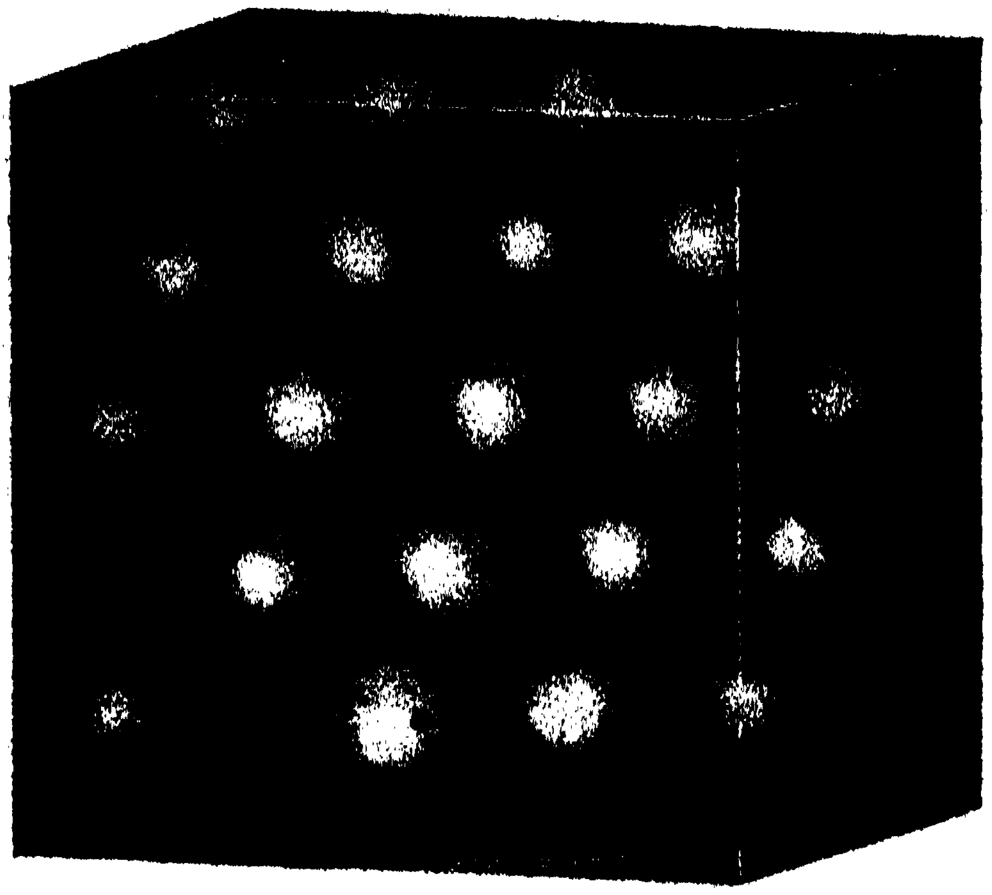


FIG. 4.—ARRANGEMENT OF ATOMS IN γ-IRON ON A PLANE OF THE FORM {111}. THE CUBE SHOWN IN FIGURE 2 HAS BEEN CUT OFF TO EXPOSE SUCH A PLANE

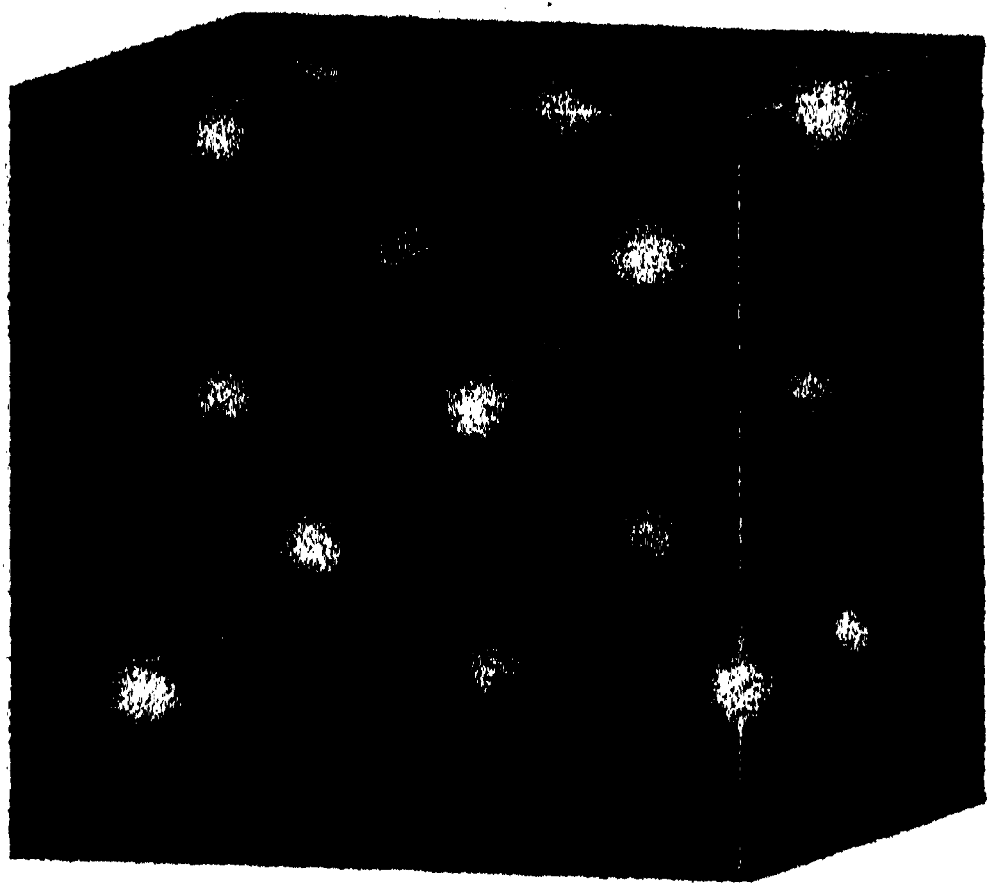


FIG. 5.—ARRANGEMENT OF ATOMS IN α-IRON ON A PLANE OF THE FORM {211}. THE CUBE SHOWN IN FIGURE 3 HAS BEEN CUT OFF TO EXPOSE SUCH A PLANE

α-crystal in the later tests. Sudden jerks and twists have another bad effect. They encourage the appearance of new crystals or at least of faults in crystal structure, such as twinning. The hot iron is readily attacked by oxygen, so that it must be surrounded by some neutral or reducing atmosphere. Hydrogen seems the best of these, but hydrogen readily penetrates hot iron and does not all come out again when the iron cools. Luckily the crystals can be heated in vacuum (below 900° C, of course) to drive out absorbed or locally liberated gases so that the effect these produce upon the magnetic and other properties of the freshly-grown crystals can be estimated.

The contacts for the electrical current which we use for local heating of the wire have also to be designed with care. These contacts must slide along the wire with little friction, must be gas-tight and must also help to keep the ends of the wire cool. A scheme that works well is to use mercury contacts, the mercury filling two cups each with a hole in the bottom just big enough to let the wire pass. The blocks in which the cups are cut are cooled partly by water passed through them and partly by the hydrogen kept flowing gently through the space around the hot part of the wire.

The wires that have passed through the new crystal-growing process are bright and smooth, with no sign upon them to advertise their conversion. A short dip in dilute nitric acid brings out the crystal structure, for the bright planes which best resist the acid are arranged in each crystal parallel to the sides of a cube, and the edges of this cube—the "axes" of the crystal—point in different directions in each. A simple form of goniometer is used to find the directions of these edges which are, of course, normal to the reflecting surfaces left by the etching, and the position of the wire axis with respect to the crystal axes is thus determined. Besides these optical measurements X-ray pictures have been taken in some cases and microphotographs have also been used to check the conclusions arrived at. The X-ray data show that the optical method, while not very accurate, is good enough for inspection purposes, either for judging the success of a crystal-growing ex-

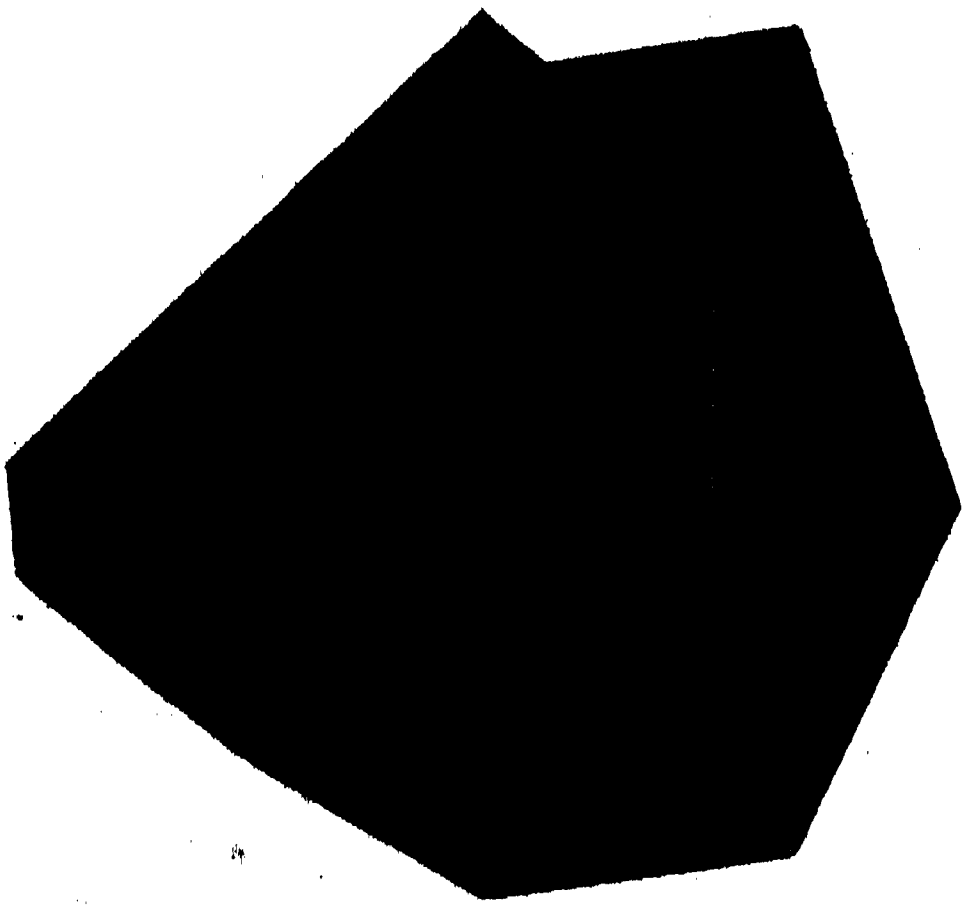


Fig. 6.—The arrangement of twins in γ-iron. Two half-cubes are shown, the common plane being of the form {111}.

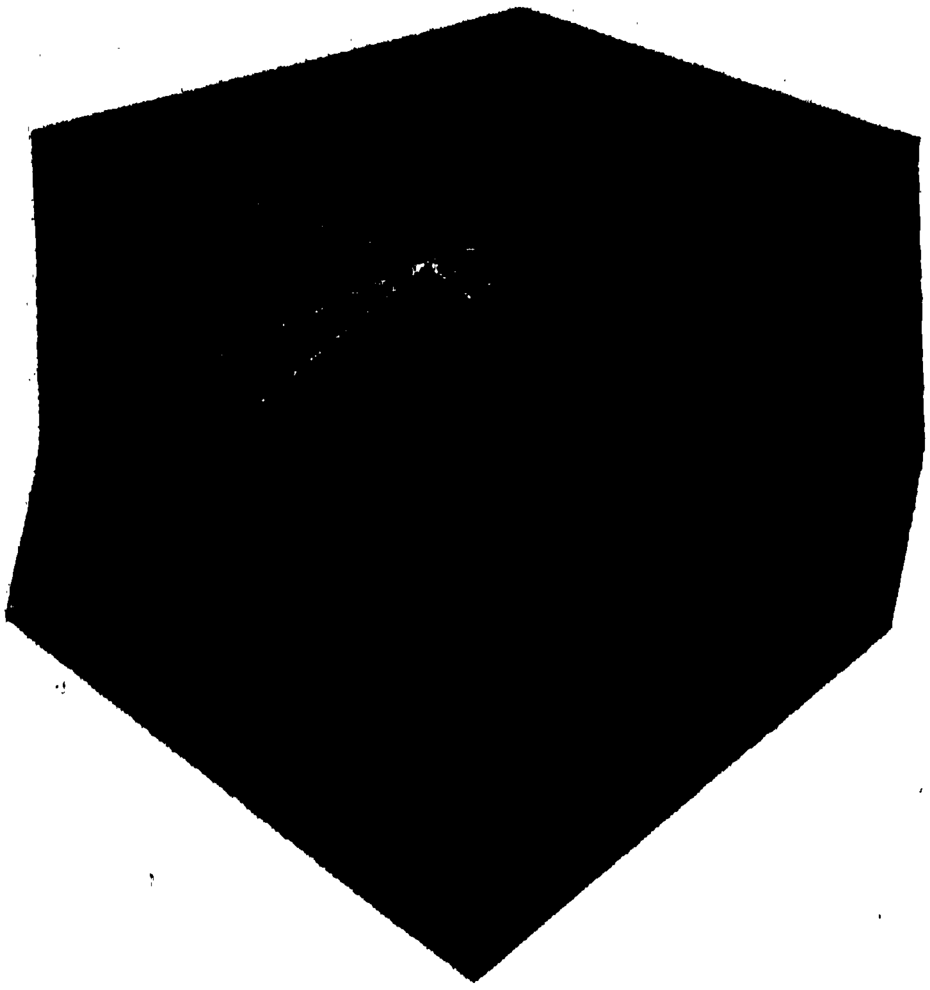


Fig. 7.—The arrangement of twins in α-iron. Two half-cubes are shown, the common plane being of the form {211}.

periment or for selecting a crystal to be given more particular study. We are not yet sure that any special orientation of the crystal axes is either preferred or prohibited.

The magnetic behavior both of freshly grown and of "degassed" iron crystals is qualitatively like that of poly-crystalline iron, but the magnetic forces necessary to reach the interesting points of magnetization curves and hysteresis loops are less for the single crystals. This is more easily seen by looking at the diagrams than by reading numerical data. Magnetostriction, the change in dimensions with magnetization, depends in amount and even in sign upon the position of the crystal axes with respect to the wire axis along which the magnetic force always acts and nearly along which the resultant magnetization must also lie. The few magnetostriction curves so far obtained are different for differently oriented crystals. Magnetization curves are not so sensitive to changes in crystal position, and our experiments are not yet complete enough to give safe results on this point.

While spending most effort on the new method we are not neglecting the chance that the old method may give importantly different results. In order to supply comparable samples we are therefore applying Professor Sauveur's method to wires identical in preparation with those used in the progressive process.

When we get a clear picture of how a single crystal of iron goes about changing its state of magnetization and what happens to its dimensions in the process, we expect to have a very fair start toward telling how a few million crystals more or less carefully packed together succeed in doing the same thing and how best to help or to hinder them. Perhaps the constructors of telephone apparatus may even succeed in obtaining in the cores of relays or of coils a new set of desirable magnetic properties.

COMBINATION, UNITY AND PEACE

By Professor **EZRA BOWEN**

LAFAYETTE COLLEGE

A STATE is an artificial entity, an imaginary person, a common law corporation, a fabricated, planetesimal mass of irresponsible power.

The term state means of course a sovereign state. A state is sovereign or it is no state at all—a province, perhaps, or a confederation or league, but not in world polity an upstanding self-sufficient individual.

The outstanding characteristic of sovereignty is jealousy. Two or more sovereignties may not overlap territorially or in any other way—except as a matter of courtesy or of temporary working agreement. Where two powers find expression in the same area, one or the other of those powers is not sovereign. Fiction such as the co-existence of the sovereignties of Maryland and the United States, of Bavaria and the German Republic, or the Commonwealth of Australia and the British Empire—such legalistic mist from the political tea kettle may be made to fill some backroom of statescraft, but in the sunlight of reason and the open air of experience it disappears. "The federal troops can not go over Maryland, and they can not go under Maryland; so I guess they will have to go through Maryland"—thus did President Lincoln reply to a remonstrant Baltimore. (Earlier remonstrances had taken the form of stoning a trainload of transient Massachusetts troops.) The "sovereignty" of Maryland or of Saxony or of Ireland is merely a political and legal convenience, a fiction, a stuffed shirt.

Sovereignty is the most jealous of human concepts. Where two sovereignties share the same bed, always one "wakes up dead." Under the Articles of Confederation it was the federal government that perished. Under that thicker blanket, the Constitution, the several states and a new federal government returned to slumber came the nightmare of the Civil War; all writhed in death pains. Next morning the federal government was breathing evenly, but there were thirty-five dead little sovereignties. That was the issue which the Civil War settled. Slavery merely furnished the test case.

The primordial, protozoan state was in all probability the family or clan. The fact that it was at bottom a biologic combination, next an economic combination and only in tertiary consideration a political combination need not prohibit, in a political study, the temporary assumption that this earliest association of human beings was a purely political entity: a number of individuals conjoined to create an imaginary person, the state, to act for them in the exercise of certain surrendered rights. The origin of the state was in *combination*, and its development has followed most conspicuously the path of further and further combination.

Combination meant many things; most of them were, however, far beyond the understanding of primitive man and therefore incapable of furnishing motives to combination; but one thing emerged, sharp, clear and large: Combination meant protection; more combination meant better protection. The family, in its underlying meaning a biologic unit, in its secondary meaning an economic unit, was thirdly a political unit, a fighting unit, an association to deal with violence and to deal in violence. Biologic and economic bonds resulted from forces working within the group. The political bond came mainly in response to external pressure, a pressing need for protection—the protection that the means to destruction offers against destruction. Violence is colorful, and the quiet pursuit of biologic and economic ends, somewhat dull. No wonder, then, that the war values—or more delicately, the defensive values—of association appeared supreme and became a controlling motive in all political unions.

A clan or tribe may be considered an association of families; a nation, a union of tribes; then nations combine to form great states, and states are welded into empires. Sometimes combination is effected by agreement, sometimes a state gains weight by the simple act of swallowing its neighbor. Each time, security is the motive, explanation, excuse—call it what you will—the chief result, each time, a more terrible and beneficent war-machine: terrible to the foreigner, benign to the citizen.

Combination is very old. Existence in its biologic and economic sense demands it. Combination, with its implication of organization, antedates intelligence; but when intelligence is brought to bear, combination and organization are still for protection, for war. From the dawn of intelligence to the moment that is passing, the world has been organizing—organizing for war: War between families, then war between tribes, war between nations, and war between empires; but within the family, within the tribe, within the nation, within the empire: peace.

Combination, recombination and further combination, with always more terrible wars between the growing units, but more perfect peace within—how long can this principle continue? Hardly until to-morrow. Its explosion point is upon us now; for in unity all combination meets an end. And in this case, unity means universal peace. . . . Clans have combined to form tribes, tribes to form nations, nations to form vast states, states have joined in empires—an age-long process of organizing and reorganizing for internal tranquility and for external violence. Into what can the great states and colossal superstates of the present world, now organized (or organizing) for the next and most terrible of wars—into what can they combine but unity? Peace within and war without; but when all without is all within, there is an end: peace universal.

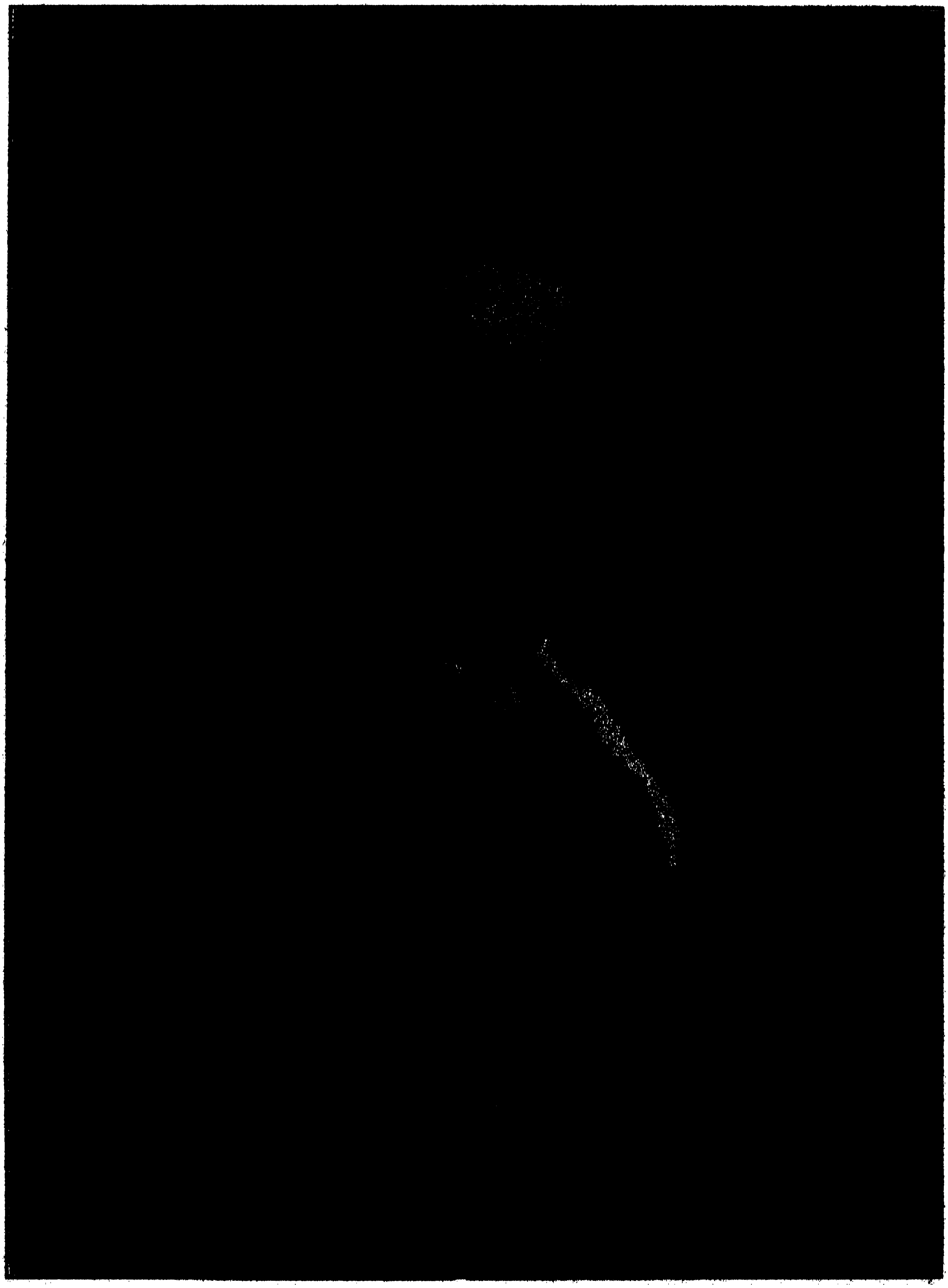
How will this final unity be achieved? Will some present state gobble her sisters one by one till she swells to world proportions? Or will there be a new state composed of present states united—united by agreement, by covenant or constitution? These two have been the modes of combination in the past. *There is no third.* The first was always swift, sure and usually final; the second, slow and halting—for it must come by conclave and agreement; one or two false steps must precede enduring union: well-meaning gestures like the German Zollverein, the first American Confederation, the League of Nations. Will the universal and final state appear by agreement, or will one present state impose its system upon the world?—will reason be the unifying flux, or can "blood and iron" alone bring unity? This only remains in question.

Darius, Alexander, Napoleon and William II may have been the unconscious instruments of a wide-spread will toward world unity through violence. But the most successful of past attempts suggests remoteness and instability in the fulfilment of any present hope. The World's unique attempt at unity through agreement, the League of Nations, though present in the flesh—or rather, partial skeleton—holds out scant hope to those who would complete this skeleton, clothe it in flesh and embue it with the sovereign spirit. But how often—and how suddenly—the whirling of time visits its revenge upon the sluggish human will.

Combination has always offered great advantage: but always great sacrifice has been demanded. In this final congregation, as in all earlier combinations, but one sovereignty will emerge. There is the rub! We can not give our sovereignty, and keep our sovereignty. The new world organization will be sovereign, or it will be a thin pink peace mist, upon which the rising red sun of war will make a hasty breakfast. Here is the sum of human experience with political consolidation.

The principle of combination—to the end of greater security—has not progressed continuously. There are more sovereign states to-day (1927) than there were ten years ago. Other periods in the world's history have seen temporary increase in the number of independent nations. But from century to century a decrease in number and a corresponding increase in the weight of sovereignties has been constant. Few modern nations are so small that they do not contain several ancient states. To uncover them it is necessary only to turn back a few pages of history, archeology or ethnology. A constant decrease in numbers is, certainly, a trend toward unity; this is our thesis.

Independence, with the constant horror of a violent end, or political combination with the prospect of causing someone else's violent end: this was always the choice. The gentle force of reason often sufficed to bring combination. This time it should certainly prevail. For, although the sacrifice that each combining state must make is just what it has always been—enough of its own power to ensure life to the new super-power—this time the gain is indefinitely greater. Earlier combinations were always offset by counter-combination. A Triple Alliance was formed; it was counter-poised by a Triple Entente; the gain was temporarily or relative. This time, the net prospective gain is absolute, total, final. As ever, each conjoining state must deduct loss of sovereignty from prospective profit. But from that net there need be no deduction—this time, no loss from counter-combination. The end is not merely a greater degree of safety derived from a greater power for violence: the end is world unity and peace.



DR. HENRY FAIRFIELD OSBORN

PRESIDENT OF THE AMERICAN MUSEUM OF NATURAL HISTORY AND RESEARCH PROFESSOR OF ZOOLOGY IN COLUMBIA UNIVERSITY, WHOSE SEVENTIETH BIRTHDAY WAS CELEBRATED ON AUGUST 8. THERE WAS PRESENTED TO HIM BY HIS COLLEAGUES AND FRIENDS A VOLUME CONTAINING NEARLY A THOUSAND SIGNATURES, TOGETHER WITH A CUP. LATER THERE WILL BE A RECEPTION AND THE PRESENTATION OF A FUND FOR RESEARCH WORK.

THE PROGRESS OF SCIENCE

EDITED BY EDWIN E. SLOSSON

Director of Science Service

FLUID FUEL

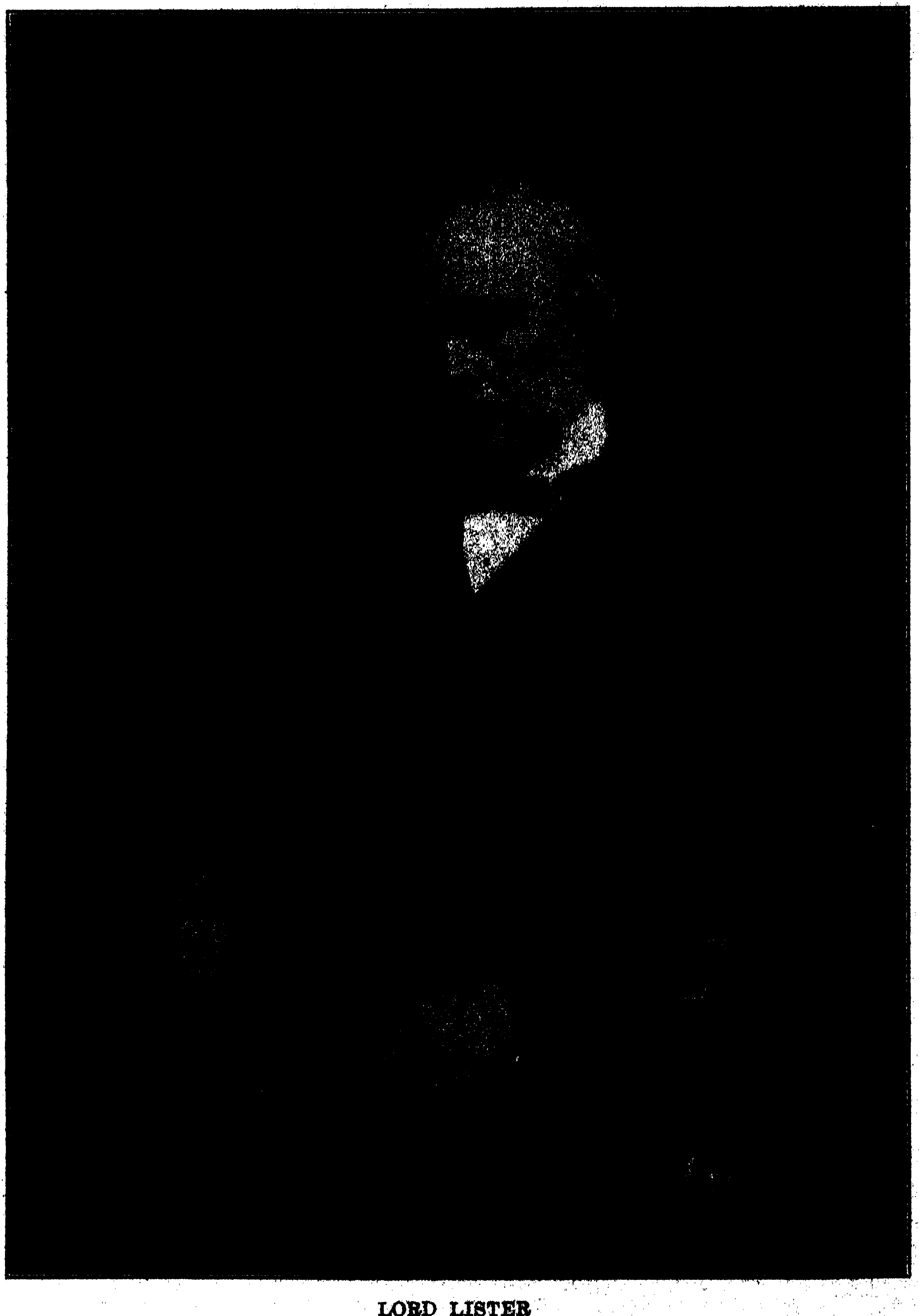
THE mobility of man is measured by the mobility of the power he employs. Consequently, the efforts of technologists are now directed toward increasing the fluidity of fossil fuel. The finer the particles the more fluid the form. The cheapest and most abundant source of energy is coal but this is solid and deeply embedded in the rocky matrix of the earth's crust. From this matrix the coal has to be torn loose by explosives and then broken into lumps small enough to be shippable and shovelable. Putting fuel into powdered form it can be blown into a furnace on a blast of air. By combining it with hydrogen we can reduce the carbon to a liquid form and by heat convert it into a gaseous state where all the molecules are free and independent. Fuel in this free and fluid form, like gasoline and Diesel oil, has given us the internal combustion engines and made possible the automobile, the airplane and the submarine.

But the atom is not the limit of divisibility, although that is what its name implies. As we now know, it is possible to break up the atom, and its finer fragments, electrons and protons, afford us a still more fluid form of energy, the electrical current. To transport solid coal from the mine to the factory requires a large part of its power. To transport water from the mountain to sea requires no power. It will flow down hill of its own accord if you will only provide it with a sloping channel or an empty pipe. To transport electricity from a point of high potential to a point of low potential requires no power. The current will flow down hill of its own accord if you will only provide it with what is for it an empty pipe, that is, a copper wire. And the electric current will travel far faster than the coal train or the flowing stream. So the efforts of inventors are now concentrated on methods of increasing the mobility of energy by such means as converting coal into a liquid form, or converting its energy into the electrical fluid.

The transmission of power by wire is in actual operation up to two hundred miles and has been carried on experimentally up to a thousand miles. The wireless transmission by ether waves traveling at the rate of 186,284 miles a second is a vision of the future. Since such a speed is virtually instantaneous for all points on the globe the limit of mobility is here attained.

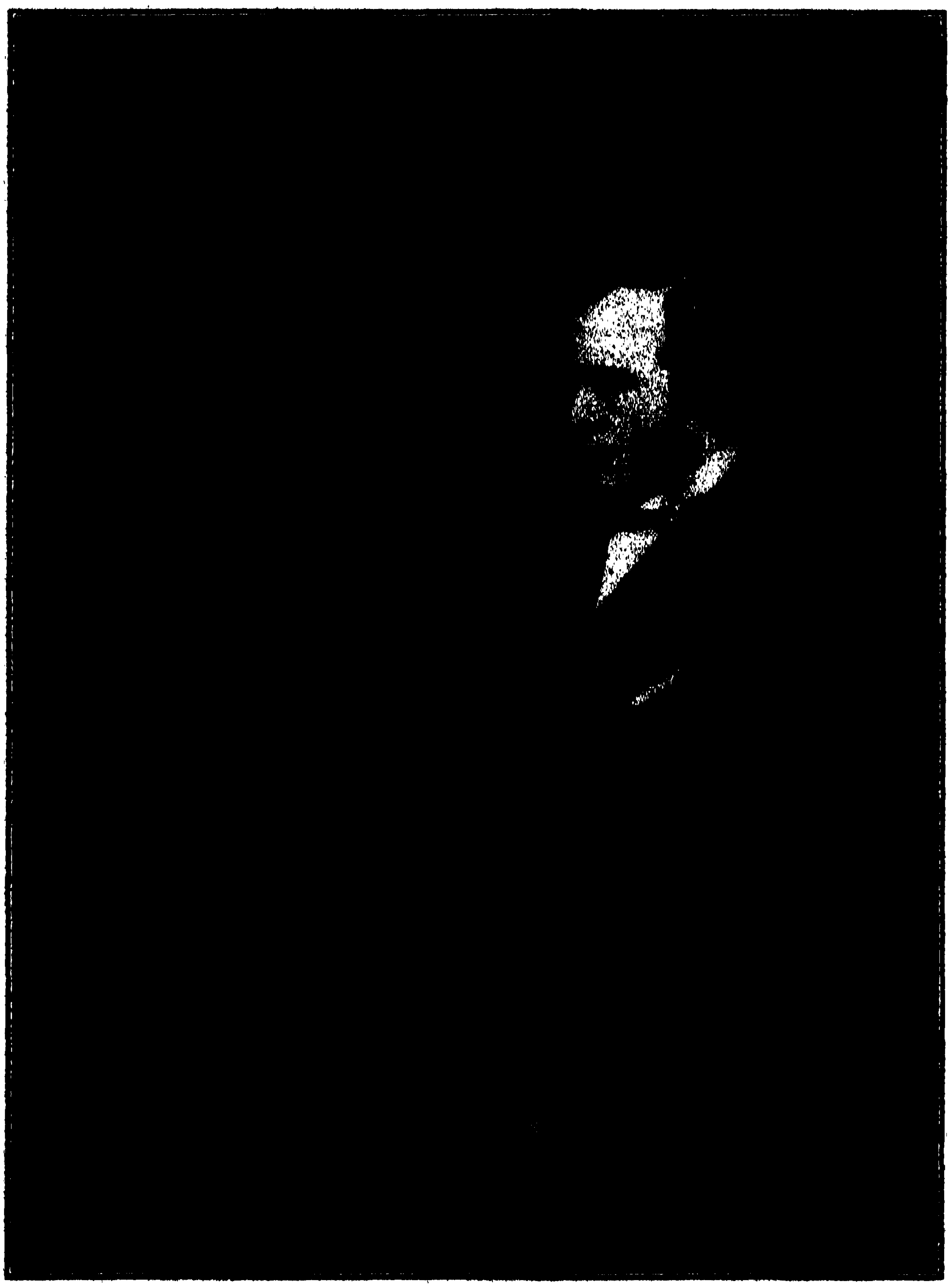
PROTECTION FROM POISON IVY

POISON IVY, the bane of the vacationist's existence, is with us again. Every motor trip, every picnic, every hike through the woods is apt to be followed by a "blistered," red, intolerably itching casualty, or at least will have the best edge taken off its pleasure by the nervous anticipation that such ill consequences may follow a few hours after brushing against some seemingly innocent vine or bush. Remedies by the hundreds are recommended by doctors, by druggists, by old-fashioned housewives. Some of them work, some of them just serve to keep the patient in as cheerful a frame of mind as possible until the



LORD LISTER

THE CENTENARY OF WHOSE BIRTH IS BEING CELEBRATED. IN THE PRESENT ISSUE OF THE SCIENTIFIC MONTHLY THERE IS PRINTED THE ADDRESS GIVEN BY LISTER WHEN HE WAS PRESIDENT OF THE BRITISH ASSOCIATION. IT GIVES AN ADMIRABLE ACCOUNT OF HIS CONTRIBUTIONS TO ANTISEPTIC SURGERY AND OF THE RELATION OF RESEARCH IN SCIENCE TO THE PRACTICE OF MEDICINE.



LISTER

AS HE APPEARED AT THE TIME WHEN HE WAS CARRYING ON HIS INVESTIGATIONS OF ANTISEPTIC SURGERY.

afflicted place gets well by itself. The handling of ivy poisoning, and of its kindred ailments oak and sumac poisoning, is still in a more or less chaotic condition.

Scientific order, however, is being brought out of it by the efforts of botanists, chemists and physicians, and now there are a few standard remedies, and what is even better, standard preventives, that anybody can have his corner druggist mix up in a few minutes. There is nothing "patent" or proprietary about them; they are all old familiar chemicals, and they don't cost much.

The best remedy is axiomatically one that destroys the cause of the ailment, and it is for this reason that Dr. James F. Couch, of the U. S. Department of Agriculture, expert on poisonous plants, recommends the use of a solution of permanganate of potash to stop the itching, blistering irritation that follows contact with poison ivy, poison oak or poison sumac. Five per cent. of the compound in water is all the prescription your druggist will need. Bathe the afflicted skin freely with this solution, swabbing it on with a bit of cotton or soft cloth, and the poison will be oxidized and destroyed. This treatment leaves a brown stain on the skin, which can easily be removed in any one of a number of ways. A one per cent. solution of oxalic acid, Dr. Couch says, is the quickest means. But oxalic acid is a poison, so that if you are afraid of children getting hold of it you may use instead a one per cent. solution of sodium bisulphite, or even just plain soap and water, though the latter is a bit slow in taking off the stain. If the skin has been very much broken by scratching or otherwise and is raw, the oxalic acid will cause a temporary stinging and soap and water is preferable for removing stains from such sensitive surfaces. If the skin is very tender the solution of potassium permanganate may be diluted with water before using.

The permanganate treatment is recommended only as a remedy for poisoning that has already taken place. Persons who know that they are likely to be poisoned may prevent the plant from harming them with a wash devised by Dr. James B. McNair, of the Field Museum, Chicago. This consists of a five per cent. solution of ferric chloride in a fifty-fifty mixture of water and glycerin. This is to be washed on all exposed parts of the skin and allowed to dry there, before going where the dangerous weeds grow. The iron in the chemical combines with the poisonous principle of the ivy and changes it into a harmless, nonpoisonous compound.

MUTATIONS CAUSED BY X-RAYS

THE rate at which breeds of animals and plants can be improved will be speeded up over a hundred times if the findings made by Professor H. J. Muller, of the University of Texas, on tiny fruit flies, holds true for other living things. It has been proved in his experiments, carried on at Austin, Texas, during the past nine months, and just reported in *Science*, that in the flies X-rays affect the little particles responsible for heredity in much the same way as a shot-gun fired at a pile of pebbles would affect the pebbles. The hereditary particles become permanently transformed in all sorts of unexpected ways—the changes known as "mutations" are produced in them. Not all of them mutate at once, but here one, there another, in quite a random fashion, and sometimes, too, they are dislodged into new arrangements. Since these hereditary particles, which are known as "genes," are handed down from parent to offspring, and determine the characteristics of the next and later generations, all kinds of new traits are likely to arise among a group of offspring or grand-offspring from parent flies that were treated with X-rays. These new traits are permanent, as they are inherited by succeeding generations.

It has long been known that such "mutations" occasionally happen without X-ray treatment, and so give a chance for the breeder to improve his stock, by breeding from animals that have desirable mutations. In the same way in nature, the "survival of the fittest" mutations is thought to have brought about evolution. But the mutations that happen without X-ray treatment are exceedingly rare and it has never previously been found possible to make them occur oftener. That is why animal and plant improvement has been so slow, and why it has been necessary to raise countless thousands of ordinary individuals for each advantageous mutation that has turned up. Now, if mutations can be produced at will, all this will be changed.

It is true that, even if X-rays can do in cattle and cotton what they do in flies, the kind of mutation that will be produced can not be specified in advance, any more than this could be done in the past. Many different kinds of changes will be produced, in a hit-or-miss fashion, and the great majority of these will consist of derangements, deformities, and even fatal weaknesses. But this is also true of the mutations that occur naturally. The breeder then has to select from among all these changes the few that happen to be to his advantage, and breed from them only. There is no reason to believe that the number of desirable changes, in comparison with a given number of harmful ones, would be any less after X-rays than naturally. In fact, in the flies, many of the X-ray mutations look just like the natural ones. So the practical effect of the treatment, in producing over a hundred times as many mutations of all kinds in a given number of individuals, would really be to make unnecessary over 99 per cent. of the breeding of ordinary individuals that now has to be carried on before each mutation of a desired type is found.

While it seems a far cry from flies to four-footed beasts, it has always been found in the past that the principles of heredity found in the flies apply also to plants and to higher animals, including man himself. This raises very acutely another question, one that has at times in the past few years been debated among X-ray practitioners—whether, in treating their patients, they are not sometimes producing mutations that may crop up in future generations. If so, some of our medical practices will have to be modified, for there is no doubt that in man, as in flies, most of the mutations produced would be of a detrimental kind.

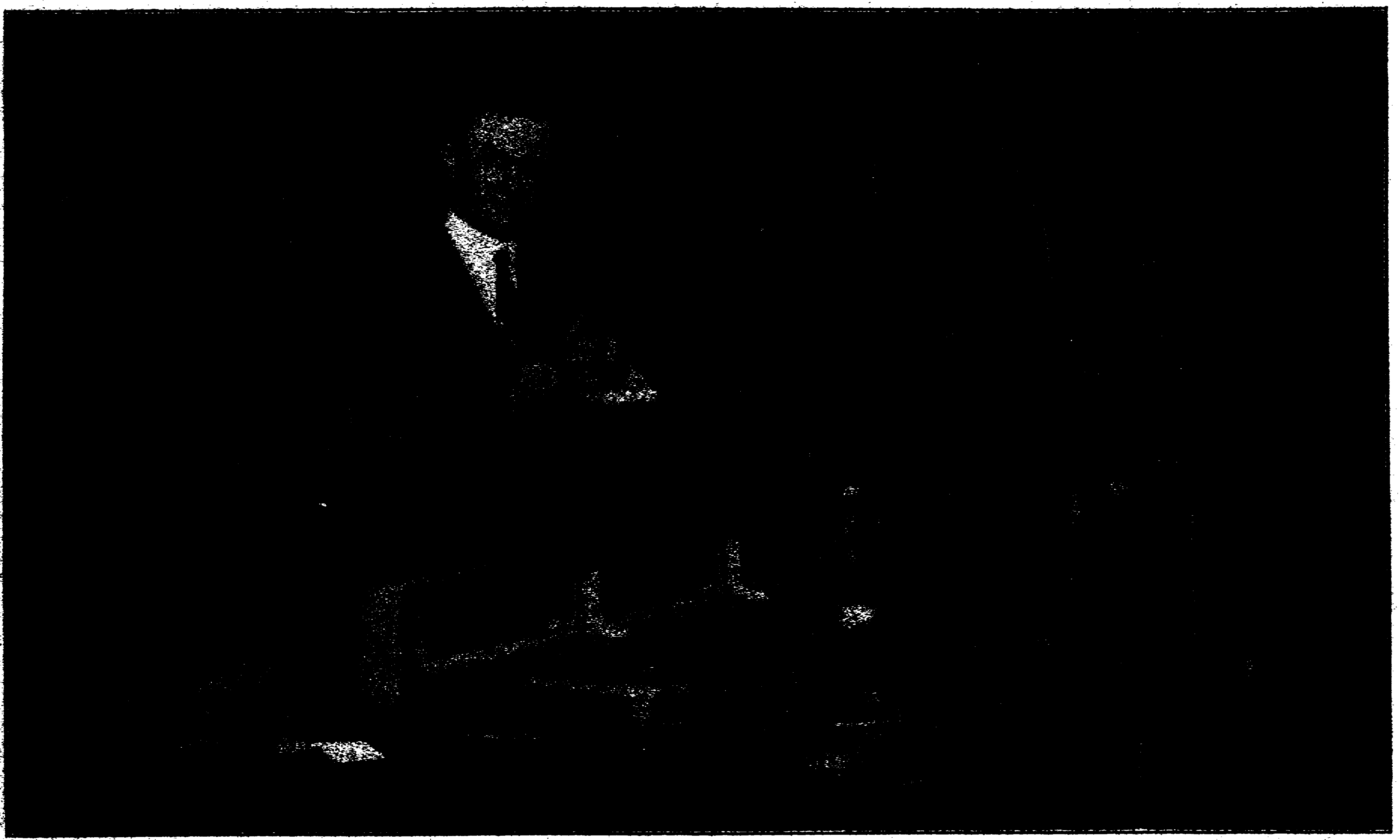
To scientists, the most interesting aspect of the work will probably be the insight which it may give us into the causes of evolution and into the nature of the little genes themselves. In fact, certain conclusions regarding the structure of genes have been drawn from the work that has already been done. These will be presented by Dr. Muller in a technical paper before the International Genetics Congress, to be held in Berlin this September.

HAFNIUM

The story of the discovery of helium has been told so often that it is commonplace. The story of hafnium is more recent, and probably less familiar, although not less romantic. It begins with the relation between atomic number and frequency of Röntgen rays, discovered in 1913 by Moseley (England), which definitely fixed the number of possible chemical elements between barium and tantalum as 16 (atomic numbers 57 to 72 inclusive). All but two of these had been identified by the time this law was announced—the unknown elements could only be referred to by their atomic numbers 61 and 72.

In 1878 Marignac (Switzerland) separated from erbium a new earth which he called ytterbium. Auer von Welsbach (Austria) in 1905 found that ytterbium was a mixture of two elements; he proposed the names aldebaranium and cassiopeium. Urbain (France) independently made the same discovery and proposed the names neo-ytterbium and lutecium. Later Röntgen-ray investigations indicated that the atomic numbers of these new elements were 70 and 71. It was then conceivable that the hypothetical element 72 might be present in the final mother liquor from which 70 and 71 were obtained, and both Auer von Welsbach and Urbain looked for it. The former did not find it, but the latter thought he did and announced in 1911 the discovery of a new rare earth which he called celtium.

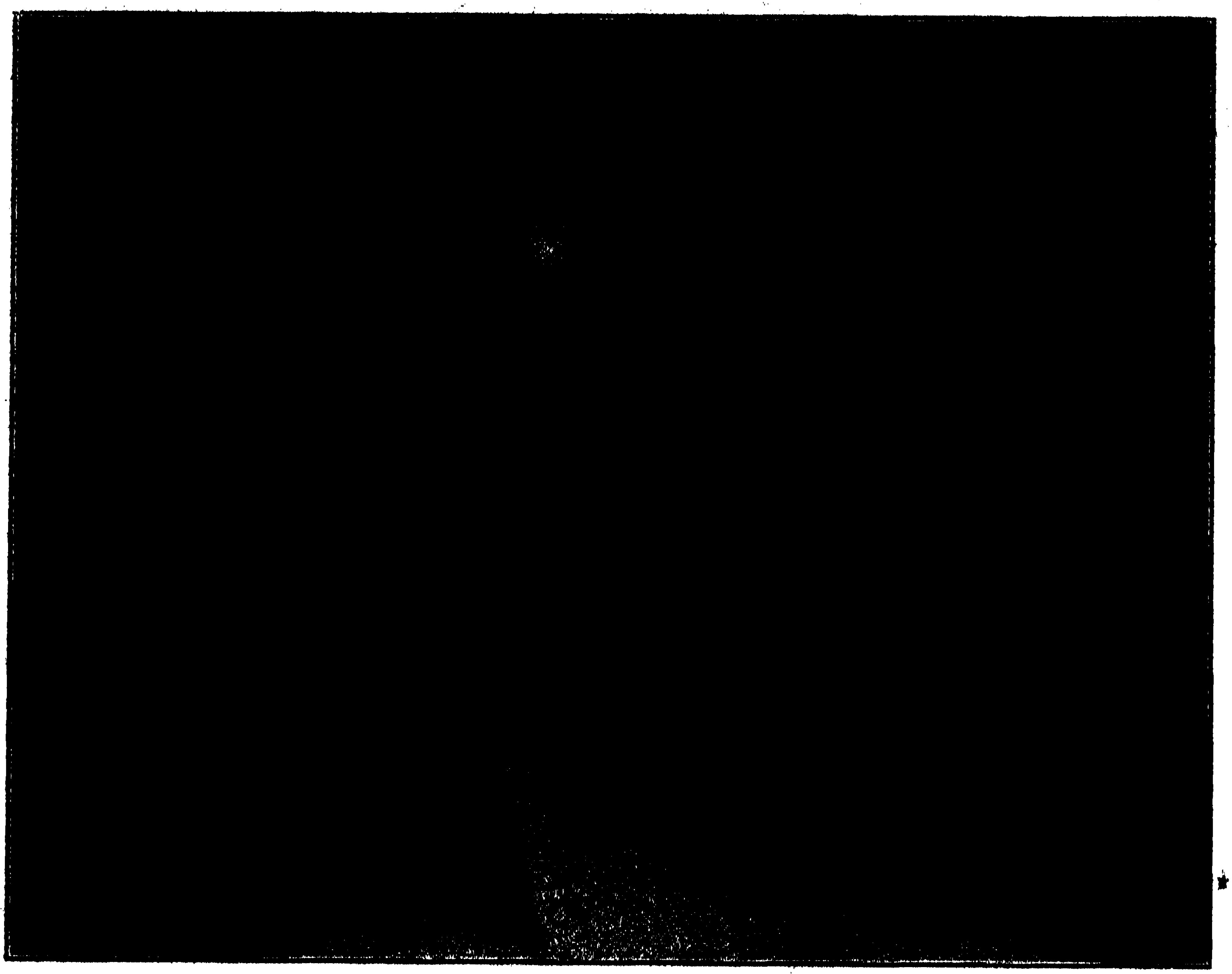
Eleven years later the quantum theory and explanation of the periodic system of chemical elements was sufficiently developed by Bohr (Denmark) to define very sharply the character of element



—*Copyright by Harris & Ewing*

DR. W. F. MEGGERS

OF THE BUREAU OF STANDARDS, ENGAGED IN THE STUDY OF THE SPECTRUM OF HAFNIUM.



THE ECLIPSE OF JUNE 29

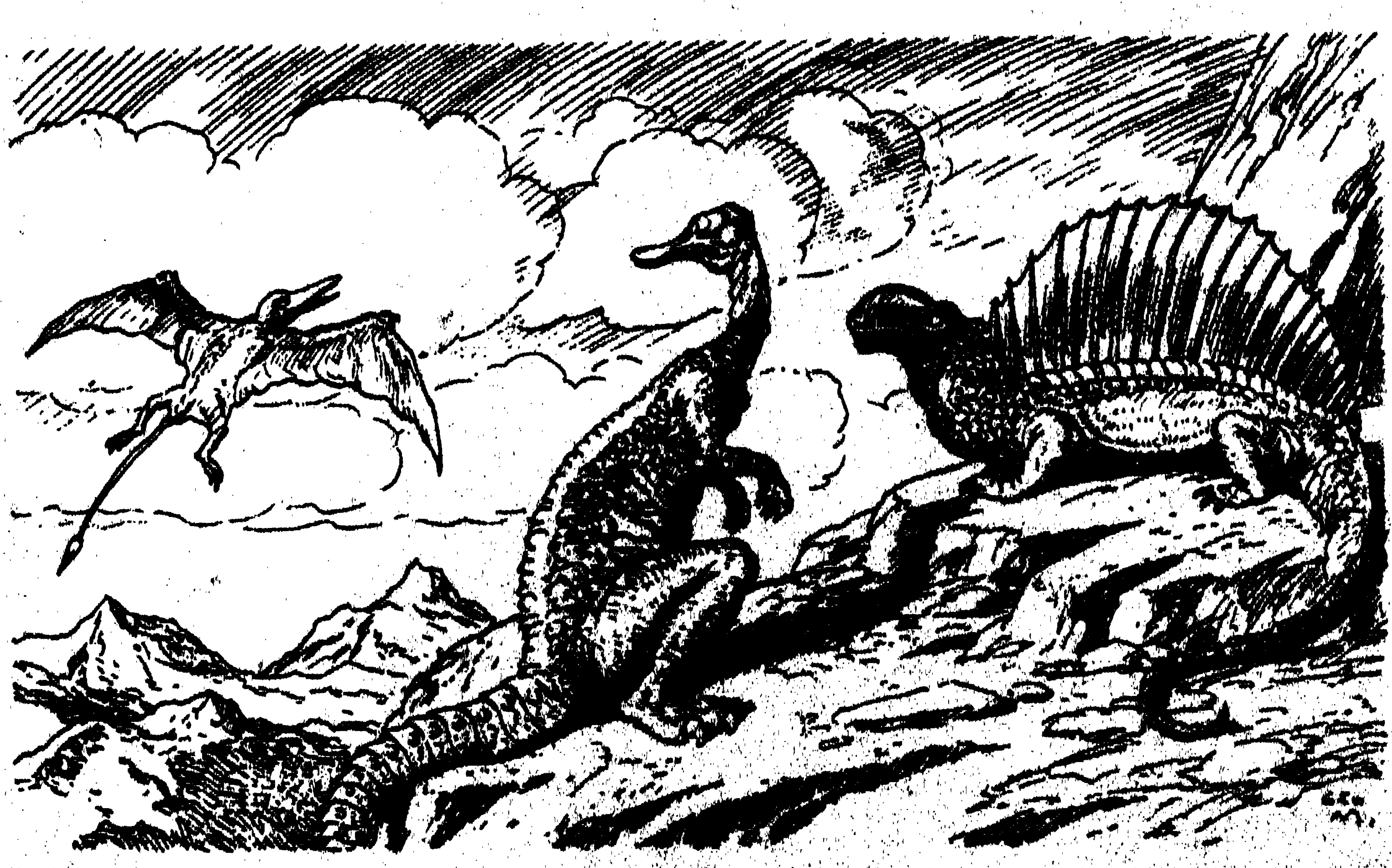
A PHOTOGRAPH TAKEN FROM AN AEROPLANE OVER BIRKENHEAD.

72. Purely theoretical considerations indicated that 72 could not be a rare earth; from the predicted atomic structure it was seen to have a close resemblance to zirconium, the atomic number of which is 40. When a sample of zirconium was carefully tested predicted lines of the Röntgen-ray spectrum of 72 were actually found. After thus identifying the new element, its presence in various zirconium minerals and preparations was detected and it was successfully separated from zirconium by chemical processes. Coster and Hevesy (Denmark) announced the discovery of the true element number 72 in a letter addressed to *Nature* on January 2, 1923. They proposed the name hafnium because it was in Copenhagen (the Latin name of which is Hafnia) in the Institute for Theoretical Physics, directed by Professor Niels Bohr, that the remarkable discovery was made.

It has since been established that all zirconium minerals contain, on the average, several per cent. of hafnium so that the new element is not really a "rare earth" in the literal sense. In fact, it constitutes between 0.0001 and 0.001 per cent. of the earth's crust. In this sense it is of the same order of abundance as lithium, copper, cerium, cobalt, boron and beryllium, and is, therefore, a thousand times more plentiful than silver and ten million times more abundant than gold. Its chemical properties are such that it is separated from zirconium with great difficulty, and without the suggestion from theoretical physics it is doubtful if its presence in zirconium minerals ever would have been suspected.

Small quantities of hafnium have been purified to a very high degree and these have been used to determine the chemical and physical properties of the new element. The atomic weight has been found to be 178.6. In addition to the Röntgen spectrum, 800 lines of the optical spectrum of hafnium have been published by Hanson and Werner (Denmark). Through the generosity of Professors Bohr and Hevesy, two samples of hafnium were presented to the Bureau of Standards for spectroscopic investigations, which are being conducted by Dr. William F. Meggers. With these, the description of the optical spectrum has been confirmed, many new lines have been photographed in the ultra-violet and in the infra-red, and a separation of the lines originating with ionized atoms from those characteristic of neutral atoms has been effected. Comparison of these data with similar descriptions of the zirconium spectra check the statement that all zirconium preparations contain some hafnium, and show that at least one sample of hafnium has been prepared almost entirely free from zirconium. The structure of the hafnium atom, the main features of its spectra, the electron configurations responsible for its spectral terms, are all known to the quantum theory; it only remains to classify the spectrum lines and thus crown the theory with inevitable, complete success.

A PIONEER



—From Punch

Very Early Reptile. "Hullo! That's something new. Flying, eh?"

His Friend (*patronizingly*). "Oh, that's young Archae opteryx, a relation of ours. Rather an amusing idea. Sporting and all that, but of no real utility."

THE SCIENTIFIC MONTHLY

OCTOBER, 1927

THE QUANTITATIVE PHASES OF HUMAN GEOGRAPHY

By Professor ELLSWORTH HUNTINGTON

YALE UNIVERSITY

GEOGRAPHY, like biology and the other sciences that deal with organic life, is passing from the stage of mere qualitative description to that of quantitative analysis. The old method was to pick out a few conspicuous examples of certain apparent relationships, and base broad conclusions on them. The new method is to take *all* the examples of these same apparent relationships, or at least all within a reasonably diverse area, and study them statistically. According to the old method, to use a familiar example, travelers observed that in certain regions the legs of mountaineers are unusually well developed, whereas among people who frequently use boats the arms are often large and the legs small. Such a contrast is to be expected, for in walking up or down hill the mountaineers exert the muscles of the legs strenuously even though the arms are idle, while the man who paddles a canoe may use his arms for hours and his legs only a few minutes. Since this type of contrast between the development of the legs and arms is found in a number of regions, geographers have naturally framed the generalization that mountains breed men with strong legs, while indented seacoasts where navigation is easy breed men with strong arms.

Such crudely framed principles are the natural and highly desirable product of an early stage in the development of a science. Sometimes they become more and more firmly established as the science adopts more mature methods. Sometimes they prove to be completely false. Most frequently they are true in part, or with modifications. In the case of the mountaineers no one, so far as I am aware, has quantitatively studied their muscular development. The preceding generalization is undoubtedly true of *some* mountaineers, but does it apply to mountaineers *as a whole?* And if the people who live in mountains have unusually well-developed legs, is this due to inheritance or simply to exercise? Do the mountains favor the preservation of people whose inherited physique makes them good walkers and climbers? Do the difficulties of the mountain life cause a high death rate or a tendency toward migration among people whose physiques fall much below the average in that respect? Or do social conventions and the prevailing ideals as to physical beauty, or as to achievement, cause the men or girls who are good walkers to be preferred as husbands or wives? And finally, even if we answer all these questions, do we not find an equally marked development of the legs among other people whose physical environment, occupation, or form of social organization obliges them to walk long distances? Such conditions might arise because people live on poor soil where the population is sparse and where the arable areas are small and widely separated, they might arise among people who depend upon hunting for a livelihood, or where the young men and boys receive military or athletic training for many years.

The paucity of our knowledge in matters of this sort is appalling. It has been excusable in the past, but it will be steadily less excusable as time goes on. Much of our ignorance is due to lack of reliable statistics. In the case of the mountaineers not only do no statistics now exist from which to answer the questions propounded above, but they are not likely to exist for generations. On the other hand, one of the chief reasons why there are no such statistics is that there has never been any demand for them. Geography has been an inexact qualitative science instead of an exact quantitative science. When the demand for good statistics becomes strong enough, they will doubtless be forthcoming. In fact our statistical material is already far in advance of our use of it. In certain phases of geography such as climatology and the related science of meteorology, exact statistics are indeed used on an enormous scale, but only within a decade or two has there been much attempt to use statistical methods for an exact study of the effect of climate upon man. In agriculture and commerce exact statistics are likewise beginning to be used as the basis for understanding the relation between physical environment and human qualities and activities. Nevertheless, they are generally used in a somewhat crude and amateurish manner even by those who have gone farthest in this respect. As a recognized tool for the elucidation of the main problems of human geography not only are statistical methods still a novelty, but they appear to be practically unknown to many geographers. Vidal La Blanche is widely recognized as one of the greatest recent leaders in French geography. Yet his book on the "Principles of Human Geography" contains no statistics aside from a few rather inexact data as to population, while the entire book is guiltless of the least hint that the broad generalizations which he makes with the greatest freedom ought to be subjected to rigid mathematical examination.

Other geographers, not only in France but almost everywhere, likewise fail to see the need of quantitative analysis. Isopleth maps, for example, are one of the most effective tools in the geographical kit. Yet when isopleths are mentioned, many good geographers have to stop and say to themselves: "Isopleths? Oh yes, they are those lines of equal intensity drawn on maps and passing through all points where a given condition has the same numerical value. Of course I am familiar with them. I use them all the time. Isopleth is merely the general term which includes a host of specific terms, such as isobar, isotherm, isohyet, contour line and the like. I use isopleths whenever I study the distribution of barometric pressure, temperature, rainfall, storms, the relief of the land or the density of population. I should never think of doing otherwise."

That is just the point. Every geographer regards isopleth maps as indispensable tools in the study of climate, weather and the inequalities of the earth's surface. Yet not one in ten recognizes that this same tool is exactly as effective in practically every phase of human geography, provided moderately good statistics are available. As I write, there lie before me three excellent recent works on economic geography and two on human geography. All are designed for students of college grade. Yet the five together contain only five isopleth maps pertaining to human geography.

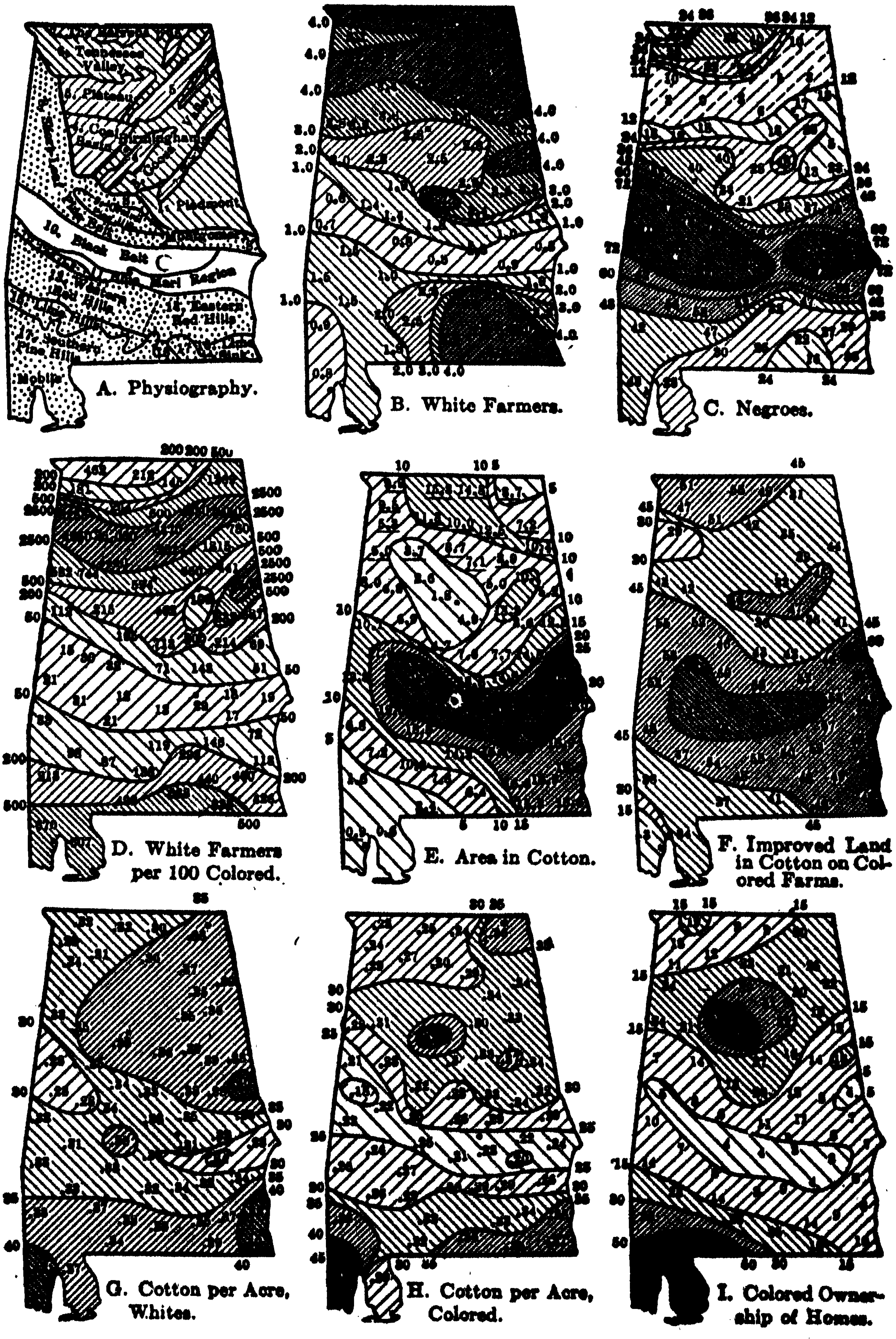
Two of these show density of population, one shows the number of cows that can be pastured per acre of land, and the other two are reproductions of my own maps of climatic energy and civilization. The number of isopleth maps pertaining to climate, on the contrary, is no less than thirty-one, while there are two showing relief.

My own experience is one reason why I write with enthusiasm about isopleth maps as an example of the use of a statistical tool adapted to the science of geography. Their use has opened a new and astonishing field of easily accessible but as yet unexplored knowledge. In the "Principles of Human Geography," published in 1920, I used seven isopleth maps of climate, five of density of population and only three of other human conditions. Two years later, having discovered the value of this tool, I put twenty-three isopleth maps of human conditions aside from density of population into a book called "Business Geography," while the number of isopleth maps of climate remained practically the same as in the previous book. Four years later, in 1926, I found that isopleth maps were helping me so much that I put fifty-three of them into the second edition of "Business Geography." Other geographers are having similar experiences with this highly valuable tool.

Of course isopleth maps are only one of many devices by which the geographical significance of statistics may be brought out. They are emphasized here partly because of my own experience, but mainly because their universally recognized value in studies of climate, relief and density of population makes them so familiar that their usefulness becomes almost self-apparent as soon as it is pointed out. The use of so effective a tool, along with others which can not here be discussed, is bound to spread rapidly with the new realization that geography must be quantitative as well as qualitative.

In order to make our discussion concrete, let us use the state of Alabama as an illustration of the way in which the quantitative study of a region by means of isopleth maps either brings out interesting relationships which would otherwise remain buried in census tables, or at least clarifies relationships which are already known, but which are only understood vaguely in the old qualitative way.

Figures 1 and 2 present eighteen maps selected from a much larger series which can easily be constructed from census data, provided the investigator takes the trouble to reduce various types of figures to the form of ratios. The importance of using ratios rather than crude quantities can scarcely be overemphasized. Of course the quantities are the first thing to be ascertained, for they are the indispensable foundation, but when comparisons are to be made it is generally desirable to reduce the qualities to ratios. For example, if one would really understand the relation of manufacturing to the life of one region compared with another, one must know not only that each region produces so many million dollars worth of goods per year. One must also know the value of the goods *per capita,* for example, or per square mile, per native white inhabitant, per factory worker, per mile of railroad, and in proportion to many other factors. One must calculate ratios of various other sorts, such as the percentage of iron goods, child workers, large factories, piece workers and the like. Only thus can one region be adequately compared with another, for the mind can grasp ratios far more easily than absolute figures. Moreover, it is indispensable that the percentages or other ratios be placed upon maps, for only the most unusual minds can otherwise visualize the geographic relationships.



A. Physiography.

B. White Farmers.

C. Negroes.

D. White Farmers per 100 Colored.

E. Area in Cotton.

F. Improved Land in Cotton on Colored Farms.

G. Cotton per Acre, Whites.

H. Cotton per Acre, Colored.

I. Colored Ownership of Homes.

FIG. 1. MAN AND THE LAND IN ALABAMA (PART I)

To return now to Alabama, the problem to be solved in the present illustration may be stated thus: The so-called Black Belt is famous because of its dark waxy soil which is highly fertile and is especially favorable for cotton. The old qualitative methods of geography have made us familiar with the fact that the Black Belt is agriculturally and in some other respects the richest part of Alabama, and is the place where the proportion of colored people is largest. Beyond this the geographer rarely goes very far unless quantitative methods of analysis are applied, as in the maps now under discussion. The first of these maps, A, shows the physical regions of Alabama as worked out by Dr. R. M. Harper. The Black Belt and an almost equally fertile area adjacent to it have been left white on the map in order to make them conspicuous. The other regions—those shaded on the map—may be dismissed with the statement that in both soil and relief they are in most cases distinctly less favorable than the Black Belt. Certain sections, however, especially the Tennessee Valley in the northwest and the areas immediately adjacent to the Black Belt, possess some of the favorable qualities of that belt, although not to so high a degree.

Each map in Figures 1 and 2 represents the numerical values of one particular condition of human geography. Light shading generally indicates a low degree of the quality in question and dark shading a high degree; but the words high and low are by no means synonymous with good and bad. The conditions illustrated in the maps might equally well be studied by the economist, historian or sociologist. The distinctive feature of the present study is that we are applying the geographical method, that is, are trying to understand the *distribution* of the condition in question and the relation of that distribution to the physical environment.

A casual examination of the eighteen maps leads at once to a broad generalization. In every map without exception the Black Belt and its immediate vicinity stand out more or less conspicuously as different from the adjacent areas to the north and south. Sometimes the Black Belt is characterized by the lightest shading, sometimes by the darkest, but everywhere it possesses a certain individuality. If the census statistics were based on geographical units instead of counties, which more often than otherwise overlap the geographical units, the Black Belt would be much more conspicuous on most of our maps than is now the case.

Let us briefly catalogue the respects in which the individuality of the Black Belt is brought out by our quantitative analysis. Map B shows the number of white farmers per square mile. We see at a glance that in the Black Belt there are very few such farmers, less than one per square mile, whereas in the regions of poorest soil and least favorable relief there are as many as six or eight. This condition is partly due to the presence

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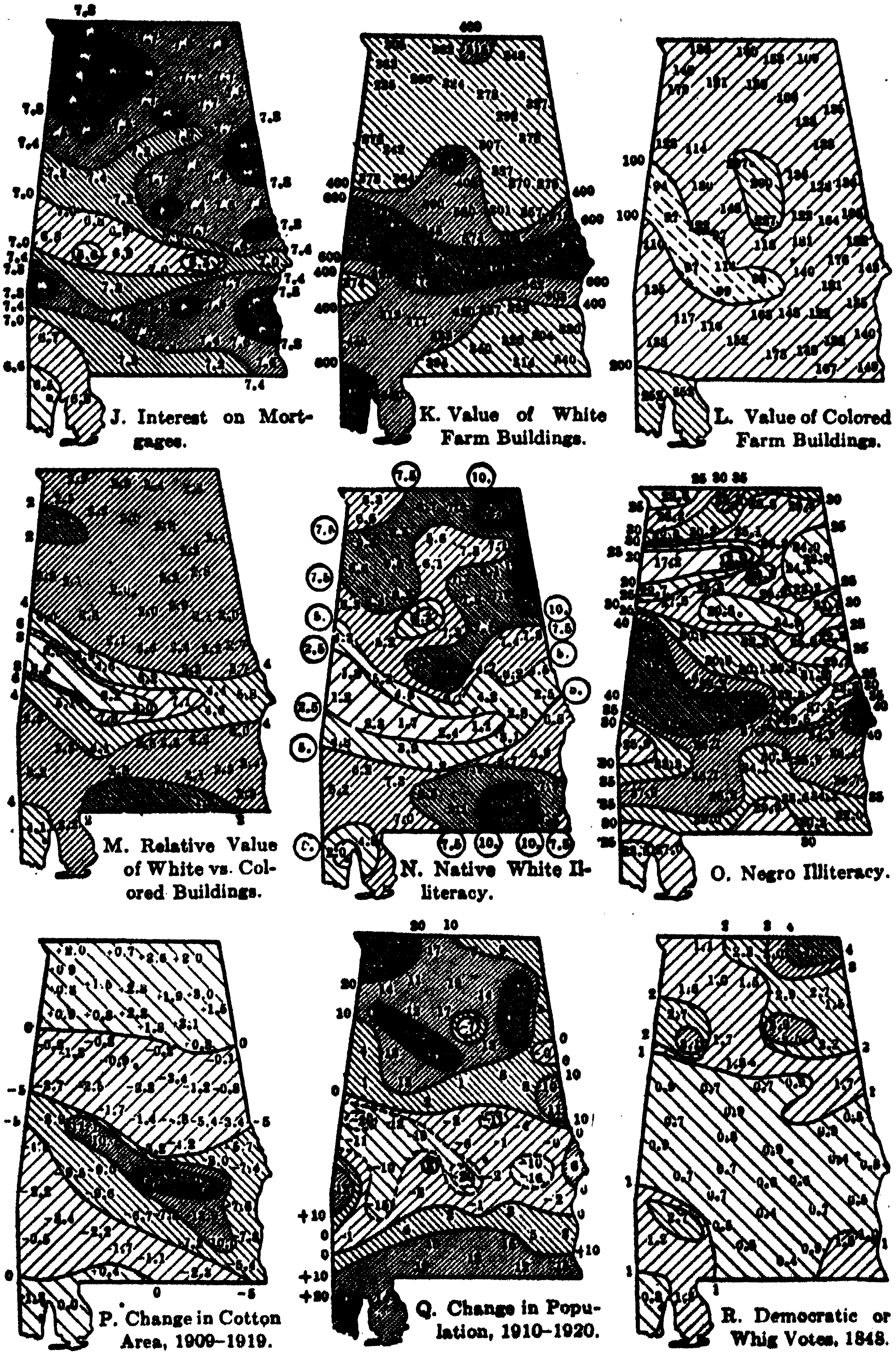
NOTE.—THE FIGURES INDICATE DATA FOR INDIVIDUAL COUNTIES. WHERE NO FIGURES APPEAR THE ACTIVITY IS EITHER ABSENT OR TOO SMALL TO BE RECORDED. THE POSITION OF BIRMINGHAM, MONTGOMERY AND MOBILE IS INDICATED ON PRACTICALLY EVERY MAP. MAP (C) SHOWS ALL THE LARGER TOWNS.

A. PHYSICAL REGIONS, ADAPTED FROM R. M. HARPER. B. WHITE FARMERS PER SQUARE MILE, 1920. C. PERCENTAGE OF NEGROES, 1910. D. WHITE FARMERS PER 100 COLORED FARMERS, 1920. E. PERCENTAGE OF TOTAL AREA IN COTTON, 1909. F. PERCENTAGE OF IMPROVED LAND IN COTTON AMONG COLORED FARMERS, 1909. G. BALES OF COTTON PER ACRE RAISED BY WHITE FARMERS, 1909. ASTERISKS INDICATE COUNTIES WHERE COLORED FARMERS RAISE MORE THAN WHITE FARMERS PER ACRE. H. BALES OF COTTON PER ACRE ON COLORED FARMS, 1909. I. PERCENTAGE OF NEGRO FARM HOMES OWNED FREE OF MORTGAGE, 1910.



J. Interest on Mortgages.

K. Value of White Farm Buildings.

L. Value of Colored Farm Buildings.

M. Relative Value of White vs. Colored Buildings.

N. Native White Illiteracy.

O. Negro Illiteracy.

P. Change in Cotton Area, 1909–1919.

Q. Change in Population, 1910–1920.

R. Democratic or Whig Votes, 1848.

FIG. 2. MEN AND THE LAND IN ALABAMA (PART II)

of colored people in the Black Belt, but many similar maps of other states where colored people are scarce suggest that this contrast illustrates a geographical principle of wide application. The general rule seems to be that in farming regions where a mature stage of culture has been reached and where the population has attained a state of equilibrium, the best farm land tends to be held in large ownings, while the poorer land tends to be subdivided into small holdings. This generalization needs further statistical verification, and there are doubtless many apparent exceptions due to the operation of other principles. The point to be emphasized is merely that when quantitative methods are employed—and only then—it is comparatively easy to determine the truth of such a generalization in any country where good census data are available.

From map C we learn that the percentage of Negroes rises enormously in the Black Belt, the minimum in any county there being close to 70 per cent. and the maximum no less than 88. The way in which the percentages gradually shade off to less than ten in the infertile plateau belt of the north and then rise toward 40 per cent. in the fertile Tennessee Valley shows how effective the isopleth method may be. Map D illustrates essentially the same thing, but in another way. It shows that while there are rarely more than twenty white farmers per one hundred colored farmers in the Black Belt, there are hundreds elsewhere, and even thousands where the conditions of farming are least favorable. Obviously the Negroes tend to be concentrated in the best parts of Alabama. The same thing is true elsewhere in the South, as has been shown by R. M. Harper, but no other method of presentation, so far as I am aware, makes the facts so clear as does the isopleth map with its summation of the whole problem, both graphically and statistically.

Passing on to map E we find that a quarter or even a third of the area of the Black Belt was devoted to cotton in 1909, while elsewhere the percentage drops with more or less regularity until it almost reaches zero. In other words, the map focusses attention upon the dangerous extent to which the most fertile part of Alabama has devoted itself to a single crop. Among the Negroes this tendency is far greater than among the whites, as appears in map F. All over the state the colored people tend to put an unduly large percentage of their cultivated land into cotton—almost never less than a third, in 1909. That is natural because cotton is the money crop, the only one on which the improvident Negro can borrow freely to support himself while the crop is ripening. In the Black Belt the Negroes actually devoted two thirds of their improved land to cotton in 1909—twice as much as to corn, hay and other food for themselves and their animals. No wonder the huge cot-

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J. Rate of interest on farm mortgages, 1920. K. Value of white farm buildings, 1910. L. Value of colored farm buildings, 1910. M. Ratio between value of white and colored farm buildings, 1909. N. Percentage of white illiteracy among persons over 10 years of age, 1920. O. Percentage of Negro illiteracy among persons over 10 years of age, 1920. P. Change in cotton area, 1909–1919, expressed as percentage of total area of counties. Q. Percentage of gain or loss in population, 1910–1920. R. Votes for Democratic candidate (Cass) per vote for Whig candidate (Taylor), 1848.

Figures 1, 2 and 6 are taken from "Business Geography," by Ellsworth Huntington and Frank E. Williams, 2d edition, 1926, John Wiley and Sons; Figures 3, 4 and 5 are taken from "Introduction to Sociology," by H. E. Barnes, J. Davis, Ellsworth Huntington and others, D. C. Heath and Co., and Figure 7 is from "Civilization and Climate," by Ellsworth Huntington, 3d edition, Yale University Press.

ton crop of 1926 with its sensational drop in prices hit the Black Belt a terrific blow. A place where so great a proportion of the productive workers are subject to a sudden and universal disaster of that kind is most unstable economically. The economic instability is likely to lead to social instability.

The next two maps, G and H, bring out the fact that the colored farmers almost universally raise less cotton per acre than do the whites. This is not surprising, but it is surprising to find that the best soil provides the lowest yield of cotton per acre among both colored and white farmers. The only explanation seems to be that where the soil is best the methods of cultivation are more careless than where the soil is poorer. In the Black Belt the actual work in the cotton fields is practically all done by colored people, even on farms run by white men; hence the poor quality of the work of the Negroes in the Black Belt is the probable cause of the low yield of cotton. This suggests that for some reason the colored people in the Black Belt are less industrious, less intelligent, or in other ways less effective than elsewhere.

Look next at the ownership of homes. How many colored people actually own their homes free from mortgages? Less than five per cent. in the Black Belt; over half in the regions surrounding Birmingham and Mobile. Does this point to economic and social inferiority among the Negroes who cultivate the soil as compared with the Negroes who engage in the kinds of work that offer themselves near large cities? Is it due to the oppression of the white man who owns the soil?

Thus far our maps seem to suggest that the good soil of the Black Belt is a handicap quite as much as a help. Map J, however, shows an advantage. The land owners of the Black Belt pay lower rates on their mortgages than do those of the rest of the state. Everywhere the rates are high according to northern ideas, the lowest county average being 6.5 per cent. in Montgomery County, but that is low compared with eight per cent. in some of the less favored counties. Here, as in so many other cases, our map suggests a geographical generalization which might well be investigated further. The generalization is that environmental conditions which cause land to be valuable for agricultural purposes tend to lower the rates of interest on mortgages, while unfavorable conditions raise the rates. That sounds like a reasonable deduction from the facts. It is borne out by similar maps of other states, but needs much further study before we can come to a final conclusion. Such studies of the manifold ways in which the quality of the land influences the people who live on it are only a part of the vast field of quantitative research which invites, nay implores, the geographer to enter it.

The next three maps, K, L and M, belong together. The first shows that the white farmers have good houses and barns in the Black Belt and relatively poorer ones elsewhere. For them, at least, the richness of the soil is an advantage. But look at Map L and note its contrast with K. Where the white farmers have the best houses and barns the Negroes have the worst. In other words, the good soil is correlated with unusual prosperity for the white farmers and unusual poverty for the colored. How great the contrast is may be judged from Map M. In the Black Belt the farm buildings of the whites are worth from five to eight times as much as those of the colored people; elsewhere only about twice as much. Is this a social, a political, a racial, or a geographical fact? Doubtless it belongs to all these categories, but its basis is geographical. The contrast is rooted in the soil.

The contrasts between the Black Belt and the surrounding regions, on the one hand, and between the white people and the colored people within the Black Belt, on the other hand, are as pronounced in respect to illiteracy as in respect to the value of the farmhouses. Map N indicates that the white people who live in the Black Belt are better educated than those of any other part of Alabama. In much of the Black Belt less than two per cent. of the white people over ten years of age are illiterate, whereas in many of the other counties the figures rise well above seven and a half per cent. and even above 10. This means a very pronounced difference in social conditions. Now look at Map O. There the contrast is the other way. Nowhere in the Black Belt does the illiteracy of the colored people fall much below 30 per cent., and in most counties it rises above 40. On the other hand, in considerable areas where the soil and relief are least favorable, the illiteracy of the colored people falls below 25 per cent. There is a great difference between a colored community where 20 per cent. of the persons over 10 years of age are illiterate and one where 40 per cent. are illiterate. The astonishing thing, however, is not merely the contrast between the Black Belt and the rest of Alabama, but the contrast between the white people and the colored people in the Black Belt itself. The whites are few in number; they own large farms; they are rich, prosperous and well educated. The colored people in the same area are very numerous; they work small farms and are tenants; they are poor; and they are highly illiterate. In a word, this set of maps suggests the broad and important generalization that good land tends to cause the population to become sharply stratified. It divides the rural population into a highly favored aristocracy and an incompetent peasantry.

Look now at the other three maps. The first of these, P, shows the percentage of the total area of each county which was added to or taken away from the cotton-raising area between the years 1909 and 1919. In the Black Belt, where the largest percentage of the land is devoted to cotton, from 10 to 20 per cent. of the whole area was changed from cotton land to land where corn or some other food crop is raised. The great fluctuations in the price of cotton during the war hit this region especially hard. On the other hand, in the parts where only a little cotton is raised, the low prices during the early part of the war did not discourage people as they did in the Black Belt, while the high prices in later years encouraged them to raise more cotton.

Closely connected with the change in the amount of cotton is the change in population. In practically all parts of the Black Belt there was a loss between 1910 and 1920. In some counties this rose as high as 20 per cent. On the other hand, the rest of the state, with only slight exceptions, gained in population, the gain being over 30 per cent. in some areas. Here, as in so many other cases, the geographical presentation of the exact quantitative facts lays a foundation for sociological and economic studies such as can be attained in almost no other way.

The same is true in regard to politics, as Professor F. J. Turner has well shown in his studies of American history. In Alabama we see in Map R that before the Civil War the Black Belt was the stronghold of conservatism. The prosperous landowners stuck to the old Whig Party as long as they possibly could. Their less prosperous neighbors to the north and south were far more ready to adopt the more radical principles of the old Jeffersonian Democracy. This seems to lead to another great geographical principle, namely that an environment which promotes prosperity also tends to promote conservatism, at least among the leaders.

At a later date, to be sure, the Whig Party was wiped out completely in Alabama so that a map of the election of 1860 would show no such contrast as that of Map R in Figure 2. But that does not invalidate the principle that where the land is rich the leaders tend to be conservative in politics; it merely illustrates another similar principle. It shows that the great climatic contrast between the North and the South provides a background which in due time produces conditions which may temporarily obliterate some of the minor contrasts due to differences in the soil. That is what generally happens. At certain periods and at certain stages of the development of a country, the minor differences due to soil, relief, mineral resources and the like become more and more obvious. Then some great change occurs—perhaps a migration, a political upheaval, or a new invention. The old tendency toward adjustment to soil, relief, mineral resources, and the like remains as strong as ever, but it is obscured by other factors such as racial capacity or patriotism which temporarily become dominant.

The facts in a single state are, of course, insufficient to substantiate the various broad principles here suggested. Hence it is especially important to discover that quantitative maps of other states suggest similar relationships. Figure 3, for example, shows the extraordinary contrast between the farms of the Kentucky Mountains which have an average value of less than $2,000, and of the Bluegrass region where the average value rises well above $10,000 and even reaches $28,000 in the region around Lexington. A score of other maps of Kentucky show a similar contrast between the two regions in agriculture, education, number of persons in "Who's Who," and many other respects. Where the maps differ from one another, as they often do, the differences commonly find their explanation in other geographical factors such as the location of railroads, the presence of minerals, the situation of routes of migration and the like. Maps of Illinois show equally interesting contrasts between the social conditions of the farming population on the poor soil of the southern part of the state where the farmers own their own land and work it with their own hands, and the extremely rich soil of the center where tenancy is increasing at a rate which

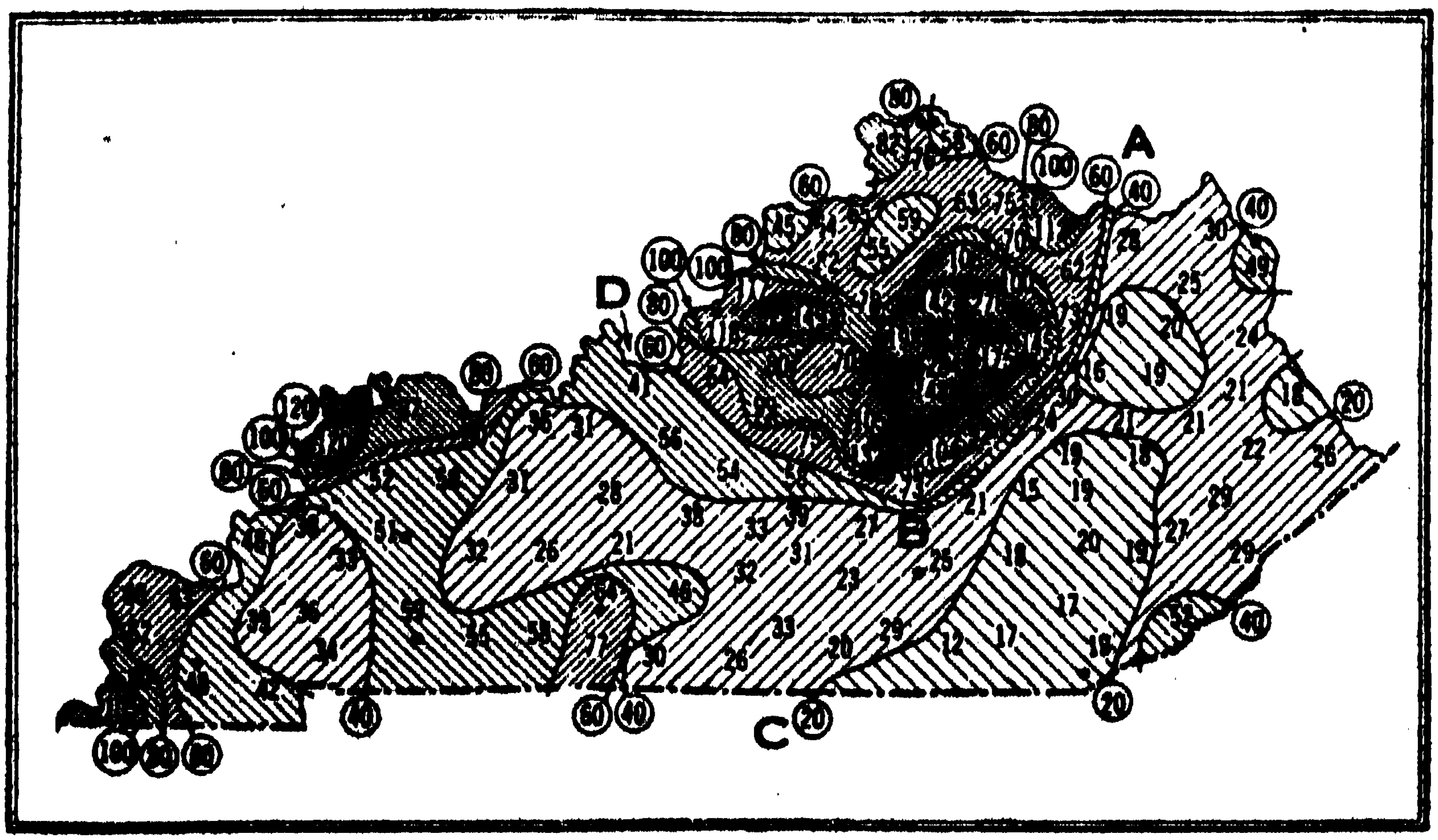


FIG. 3. THE VALUE OF FARMS IN KENTUCKY

THE FIGURES REPRESENT COUNTY AVERAGES IN HUNDREDS OF DOLLARS ACCORDING TO THE CENSUS OF 1920.

may well be alarming. Louisiana in 1927 illustrated the effect of differences not only in soil, but in the relief of the land, so that an altitude of a few feet made all the difference between normal prosperity and the loss of every thing through floods. So it goes all over the world. In general the more accurate and detailed the statistics, the clearer become the relationships between the physical environment and the life of the people.

One of the most interesting conditions which demands geographical analysis is the distribution of human intelligence. No really satisfactory method of measuring the intelligence or progressiveness of a whole community has yet been devised. One of the best, as well as one of the least known, methods seems to be the accuracy with which people's ages are reported in the census. This seems like a small matter, but it actually provides a very delicate test. The careless parent, when asked the ages of the children, does not stop to figure whether Agnes has passed her ninth birthday or not, and whether Alec is fourteen or fifteen. A careless father, or even a mother—and sometimes a careful one—may forget to mention the baby, provided there are several older children. Such parents, when faced by the census recorder, often give their answers in a hurry, only perhaps to remember afterward that they have made mistakes. Among more ignorant people, the exact age is often not known or is forgotten. The careless census-taker produces a similar result. The Smith family lives half a mile from the main road; he knows all about them or at least his wife does. Why bother to go up there. But neither the census-taker nor his wife knows the ages of the Smith children, and they forget the baby. The net result is that census statistics of age practically always show obvious inaccuracies. After the children have passed the age of five years, there is a strong tendency to give their ages as even numbers rather than odd. Ten receives an unusually strong preference, and twelve still more.

A tendency to omit some of the younger children as well as to give their ages wrong is also apparent among ignorant or careless people and among those whose mental activity is for any reason dull. This may seem surprising, but a careful examination of census figures leaves little doubt. How extreme the inaccuracies may be, and how they vary from place to place, from sex to sex, and from race to race is illustrated in Figure 4. The curves for native whites of native parentage in Minnesota, one of the best states, come near to representing the true conditions. In all countries, except under extraordinary circumstances, such as migration, famine, epidemics or other disasters, the number of children in their second year is less than in their first, for some of those under one year of age die before they begin their second year. In the same way the number of three-year-olds is less than of two-year-olds, and so on. Therefore, unless some highly exceptional condition prevails, all the curves of Figure 4 ought to descend quite smoothly from left to right, with only minor irregularities. The Minnesota curves for native whites of native parentage (A, B and C) do this. Nevertheless, they show a little irregularity, especially in 1910. Even in Minnesota there is a tendency to report too many children of the even ages, especially ten, twelve and sixteen. A few years later the girls do not want to be considered old, so too many of them report their ages as twenty instead of twenty-one; the boys want to be men, and too few report themselves as twenty and too many as twenty-one. The corresponding curves for native whites of foreign or mixed parentage in Massachusetts, (D and E) and even for native whites

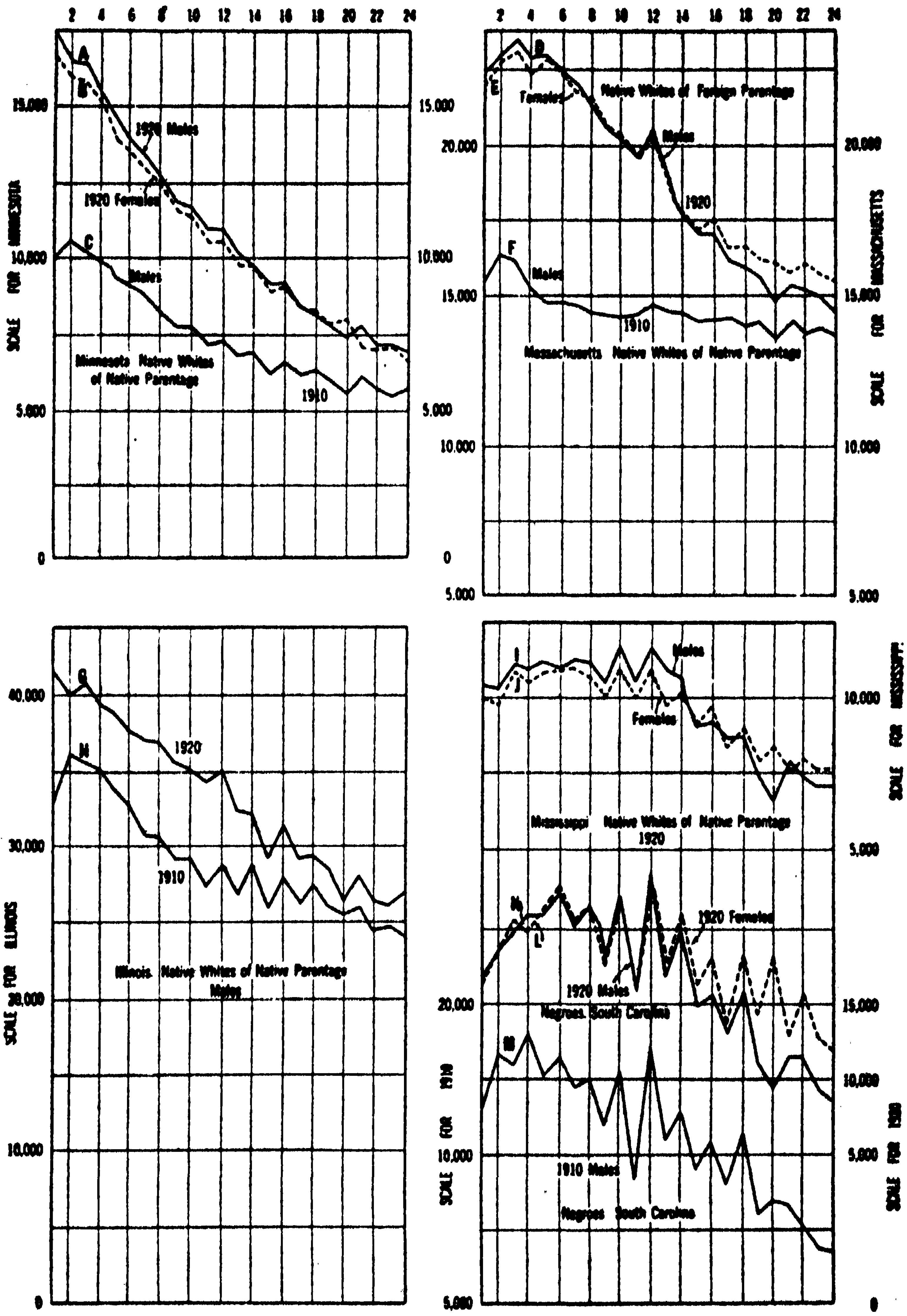


FIG. 4. NUMBER OF PERSONS REPRESENTED AT VARIOUS AGES IN THE CENSUS OF 1920

of native parentage in Massachusetts (F) and Illinois (G and H) are not so smooth as those of Minnesota. Notice the frequency of little peaks, or at least of upward bends at the ages of eight, ten, twelve, fourteen, sixteen, eighteen and twenty-one. Note also that all three of these curves show fewer children aged less than one year than between one and two years of age. Occasionally such a condition may really prevail, but very rarely, for only a large and sudden drop in the birth-rate suffices to balance the deaths which take place during the first year.

Among the native whites of Mississippi, as of all the southern states to a greater or less degree, the tendency toward inaccuracy in age returns is greatly exaggerated. Curves I and J display an enormous excess at the ages of ten and twelve, and a great deficiency among the young men at nineteen and twenty, which is made up at twenty-one. A large number of children under ten years of age are apparently forgotten, for it is quite certain that there are more children aged one to six than eight to twelve.

Still greater irregularities appear in curves K, L and M for the negroes of South Carolina, the worst of the states so far as negroes are concerned. Part of the falling off of curves K and L on the left may be because many negroes migrated to the north during the world war, so that the birth-rate actually fell, but this does not explain the extremely high position at ages 10 and 12 compared with 9, 11 and 13. Nor does it explain why the 1910 curve (M) shows the same features as the curves for 1920 (K and L) including the apparent deficiency of young children. The fact seems to be that the colored people guess at the ages of their children and forget all about many of their babies. Their curves as a whole present a graphic picture of lack of intelligence.

The delicacy of this test of intelligence is evident from the fact that in practically all states the ages of boys are given more accurately than those of girls; the native whites of native parentage are more accurately recorded than are the native whites of foreign or mixed parentage; and these in turn are almost invariably more accurate than the returns for negroes. Obviously such a test of intelligence has a wide application because it can be used wherever census returns are available. It does not depend upon man-made laws, or upon whether people live in towns or far away in the country. People who are intelligent and careful, no matter how remote they may be, report the ages and number of their children correctly, as happens in North Dakota, for example. If they are unintelligent, they report them wrongly even though they live in the greatest centers of culture.

Thus far in this discussion of age we have been considering sociological phenomena. Now let us look at the matter from the geographical point of view. Our sociological study has shown that the inaccuracy of the age statistics is a fairly good measure of the intelligence and mental activity of any given group of people. Let us frame an index number for each state of the United States, and then see what kind of map we get. Such an index number may be constructed from curves like those in Figure 4 by measuring all portions that trend upward and seeing what ratio they bear to the portions that trend downward. In a community where the birth-rate is reasonably constant and the number and ages of the children are correctly reported, the curves must slope smoothly downward from left to right in much the same way as the curves of native whites of native parentage in Minnesota in 1920. Such a curve has no upward trending portions so that the index number is zero. Computing in this general way by a method which need not be explained in detail, we obtain a series of index numbers ranging from zero to 30°. Zero means almost complete accuracy in the census returns as to both the age and number of the children; 30° means the degree of inaccuracy represented in the curves for native whites of native parentage in Mississippi.

This method enables us to draw the map shown in Figure 5. The map is based only on native whites of native parentage so that questions of race and immigration play a relatively small part. The accuracy with which people furnish the census returns doubtless de-

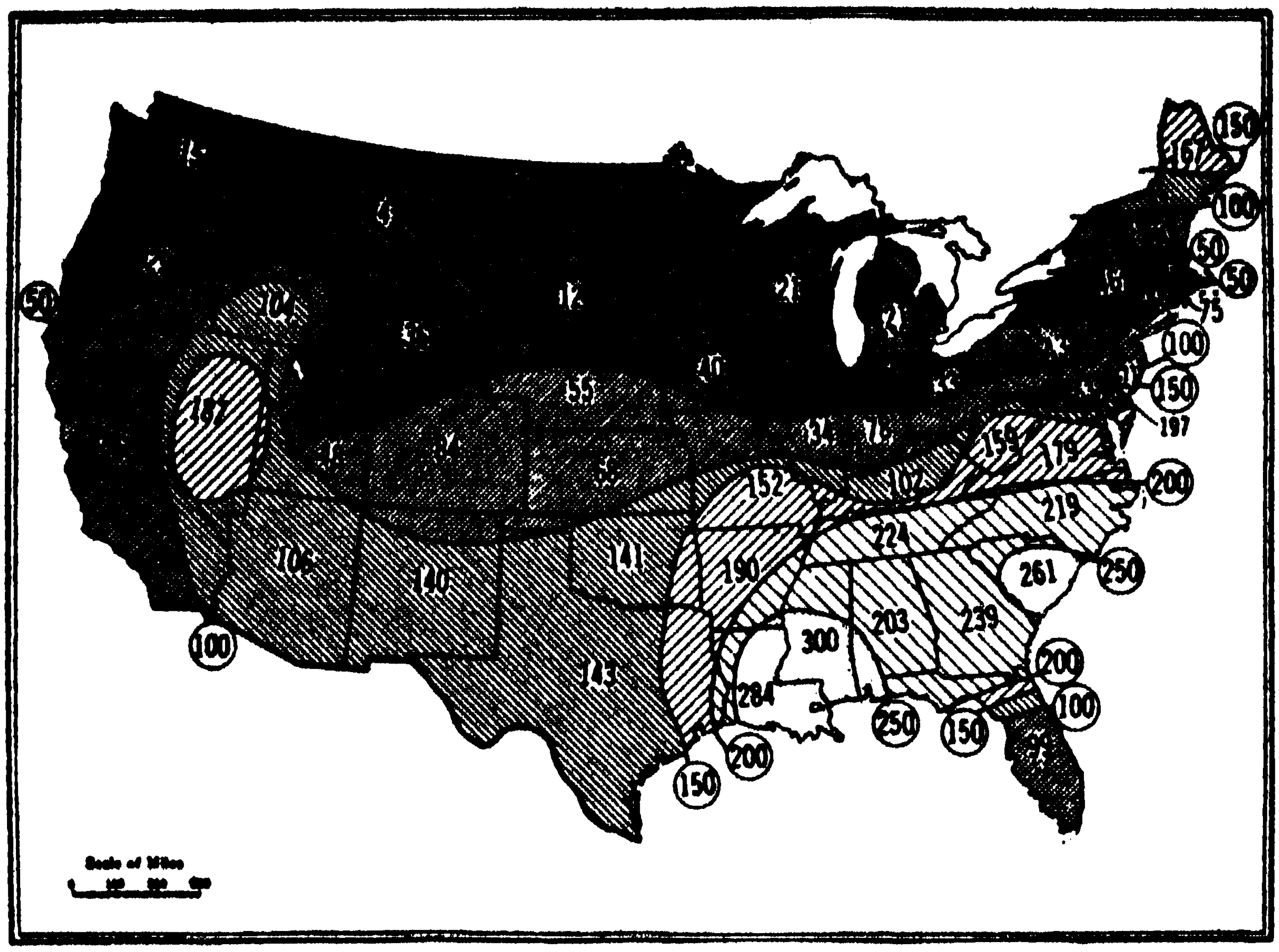


FIG. 5. ACCURACY OF CENSUS RETURNS AS TO AGE AMONG NATIVE WHITES OF NATIVE PARENTAGE, 1920

pends partly upon education. Hence the index numbers of Figure 5 are influenced by the educational systems not only of the states in question but of the states from which settlers have come. This, however, has practically no effect in blurring the differences among the southern states. Even in the north where there has been much migration, people's answers to the census questions probably depend a good deal more on their native intellect and temperament than upon the educational system in other states. Moreover, education itself depends largely on the native intellect and temperament of the people in any given region. Hence it appears that while Figure 5 does not show whether inheritance, training or environment is dominant, it does show the real distribution of intelligence and accuracy.

Turning now to the map we see in the north an area of high accuracy extending from southern New England to the state of Washington and culminating in North Dakota and Minnesota. In Maine the degree of accuracy falls off, perhaps because a large percentage of the more intelligent people have moved away and settled in the northwestern states. South of the area of high accuracy there is a general decline, the worst area being the southern states,, especially Mississippi. Another noticeable feature is a bay of poor conditions extending into the dry parts of the country and reaching its culmination in Nevada with an index of 187. Possibly the low position of Nevada, like that of Maine, may be due to migration. In Nevada the population has declined because of the decay of the mining industry. Perhaps the more intelligent people have tended to move away in large proportions leaving a relatively unintelligent residue, especially in decaying mining towns like Virginia City. That something of this kind is the case is suggested by the opposite conditions not only in regions like Minnesota, the Dakotas and Montana, which have recently received large accessions of especially energetic migrants, but also in Florida where the recent migration has brought an unusually competent set of people from other states.

Such little details where the map departs from regularity are among the best indications of its reliability. They indicate that at least two factors control the distribution of accuracy in answering the census questions. One set gives the general aspect of the map high in the north, low in the southeast, high on the Pacific coast, and relatively low in the mountain states. This first factor, as we shall show in a moment, is presumably climatic. The other factor, which may account for the low conditions in Maine and Nevada, the very high conditions in the Dakotas and the relatively high conditions in Florida may be migration.

But regardless of the causes, the fact remains that by quantitative methods such as are here illustrated we are able to produce a highly accurate map showing the distribution of the phase of intelligence denoted by the special criterion here chosen.

Suppose now that we make similar maps of various other conditions which indicate either intelligence or some form of special ability. Then we may put all the criteria together and by obtaining their average procure a fairly reliable index figure showing the position of one state compared with another in the general conditions which are usually supposed to indicate intelligence and progressiveness. I have made maps in this way of the following conditions:

(1) Education, as determined by combining the following criteria:

(a) Percentage of native white children 7 to 14 years of age who attend school.

(b) Approximate percentage of white young people eighteen years of age who graduate from a four-year high-school course.

(c) Average number of days per year that pupils in the public schools are actually in attendance.

(d) Average salary of teachers. (e) The excess of young men over young women among students eighteen to twenty years of age.

The map thus made shows that in a relatively narrow belt extending from southern New England through New

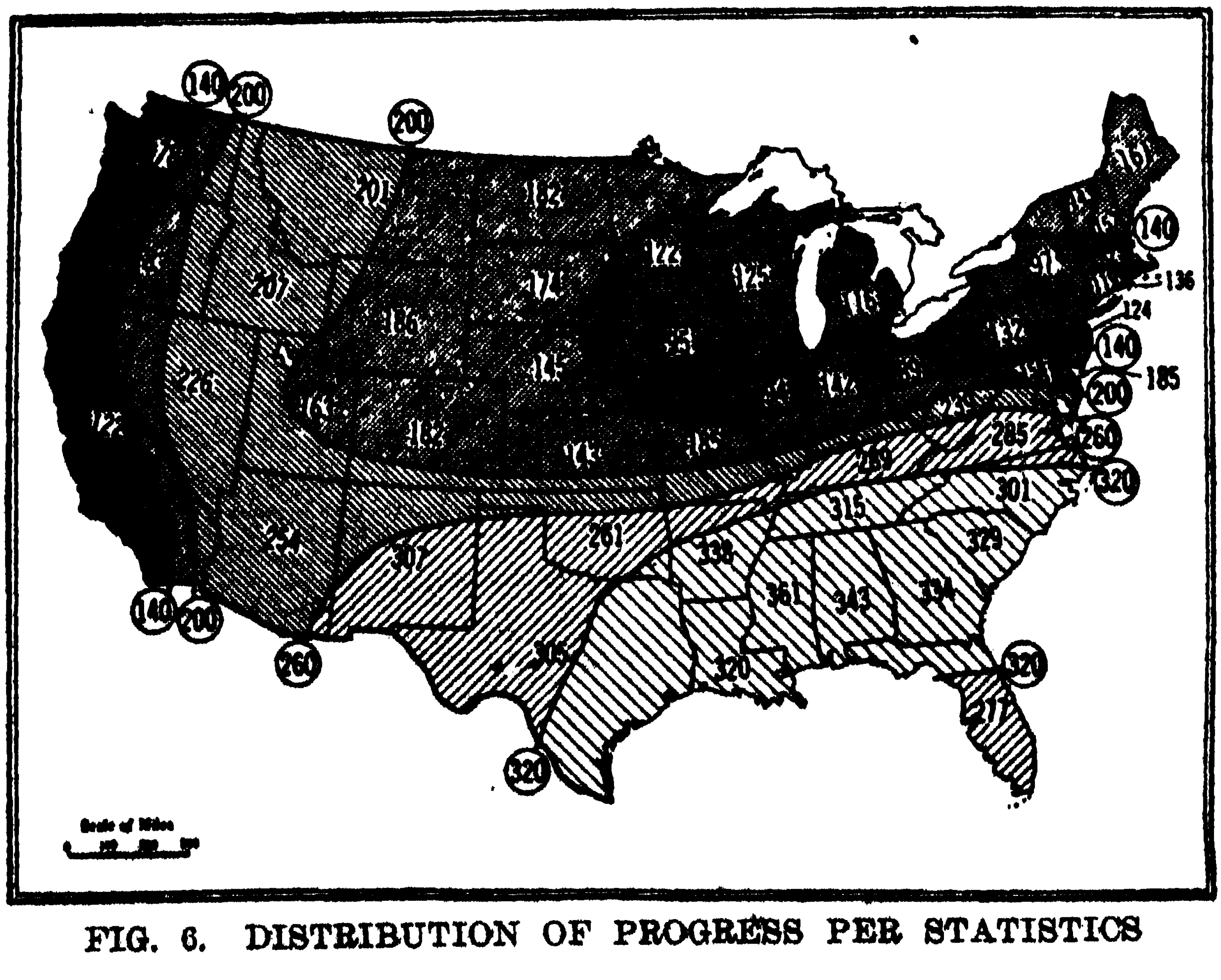


FIG. 6. DISTRIBUTION OF PROGRESS PER STATISTICS

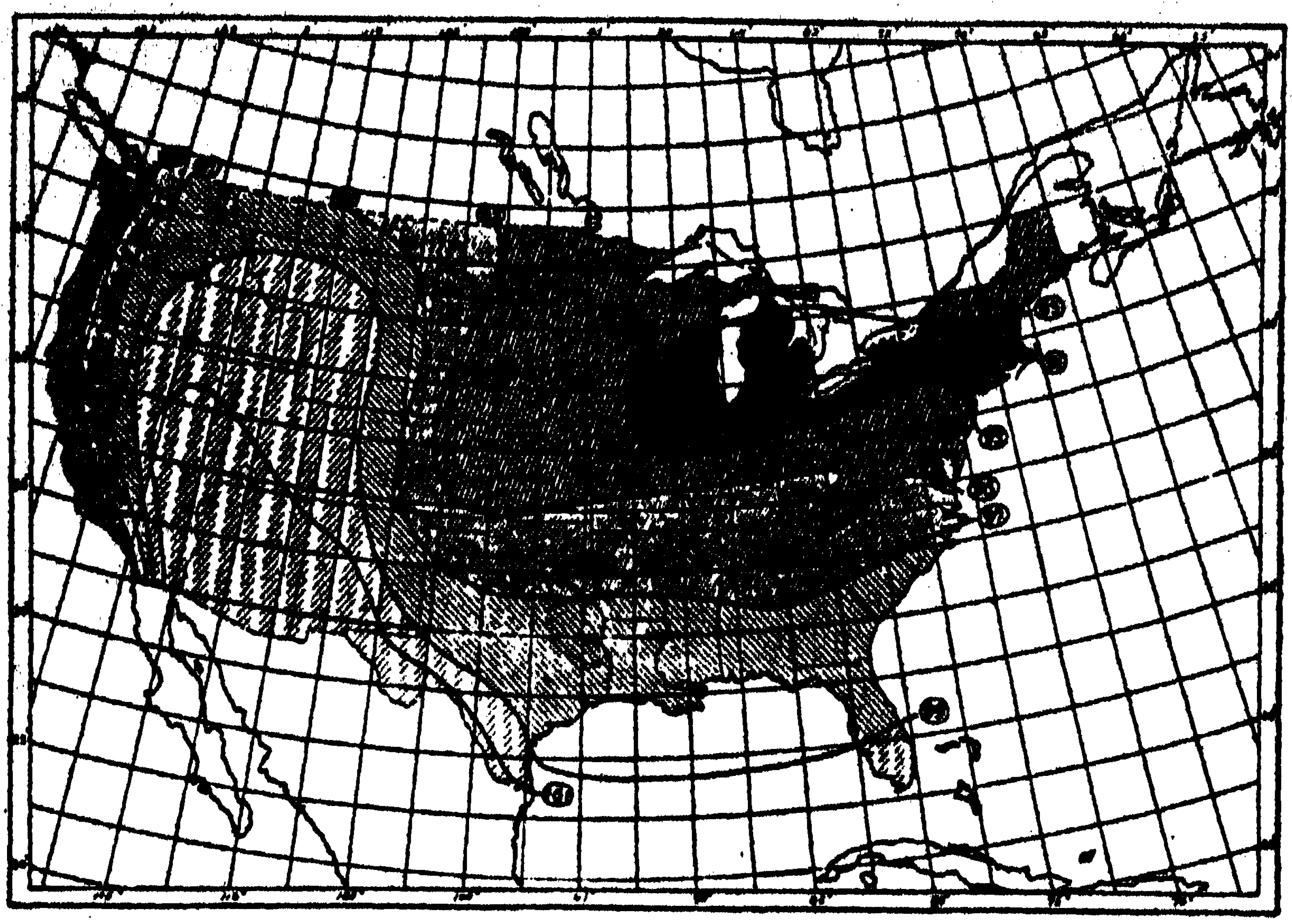


FIG. 7. DISTRIBUTION OF CLIMATIC ENERGY

York, but not Pennsylvania, and continuing to Illinois, the general conditions of education are excellent. The same is true in Utah and on the entire Pacific coast. In those places, on the whole, a large percentage of the children are in school, a large proportion graduate from the high school, the school year is long and the pupils are regular in attendance, the teachers are well paid, and many boys as well as girls continue to study after the age of eighteen.

(2) Health as measured by the statistics of insurance companies;

(3) Illiteracy among all native white inhabitants over 10 years, as given by the census;

(4) Income per capita during 1919, 1920, 1921, as determined by the National Bureau of Economic Research;

(5) Percentage of professional people among the gainfully employed population;

(6) Percentage of gainfully employed persons engaged in manufacturing;

(7) Facilities for transportation as determined by railway mileage per capita and square mile, expenditure on public roads per square mile, number of trolley cars per capita, and number of automobiles per capita.

Each of these seven criteria gives a map which in important respects resembles the map based on the census data as to ages. In order to combine these eight factors, the best state in each respect is ranked one, the next two, and so forth until the worst is forty-eight. When all the ranks thus obtained are added together, we obtain the index numbers shown in Figure 6. This map is by no means perfect, but it seems to represent the best approximation yet obtained to a statistical index of the intelligence, progressiveness and activity of the people of the United States. It has the advantage of providing a definite numerical value, uninfluenced by personal opinion except in the matter of choosing the criteria. It should be noted, however, that almost any other set of reasonable criteria gives approximately the same result. Moreover, Figure 6 is almost exactly like a map of the distribution of progress according to the opinions of 25 uncommonly well qualified judges.

More significant than this is the fact

that Figure 6 closely resembles Figure 7. This latter is a map of climatic energy. In other words it is a map of human energy as it would be if energy depended only on climate and if all persons in all parts of the United States were exactly alike in physique, intelligence, training, and health, except so far as health depends upon climate. The details as to how it is constructed have been fully explained in "Civilization and Climate" and elsewhere. Here the point that concerns us is that it represents another example of the application of quantitative methods to geographical problems. A direct comparison of the maps of climate and of general intelligence and progress is possible. We can also test the relationship by means of dot charts, correlation coefficients, and other mathematical methods such as are used by biologists and psychologists for similar purposes. We shall not do this here, however, for what we are aiming at is not to show the relation between civilization and climate, but to point out the way in which the use of quantitative methods increases our ability to solve the great problems of geography. In spite of the highly variable human element, geography will probably some day become a relatively exact science. This does not mean that it will be exact in the sense that physics is exact. Nevertheless we shall be able to analyze numerically the effect of almost any given environmental factor or combination of factors. The change which will thus result will be as profound as has been the change from the rude maps traced by the savage in the sand to the highly exact maps now made by modern triangulation.

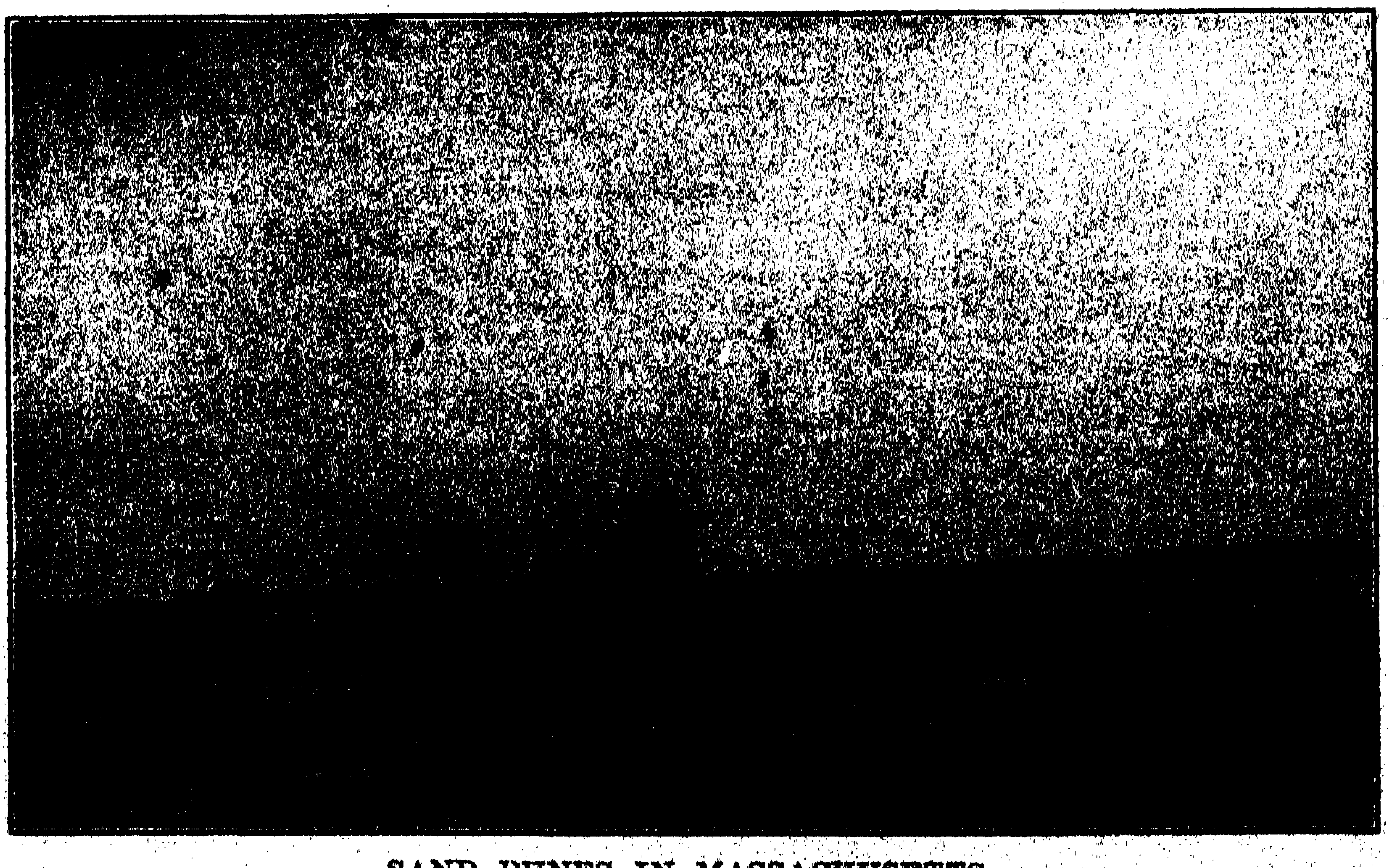
DESERTS AND SEMI-DESERTS

By Dr. **CHARLES W. TOWNSEND**
IPSWICH, MASSACHUSETTS

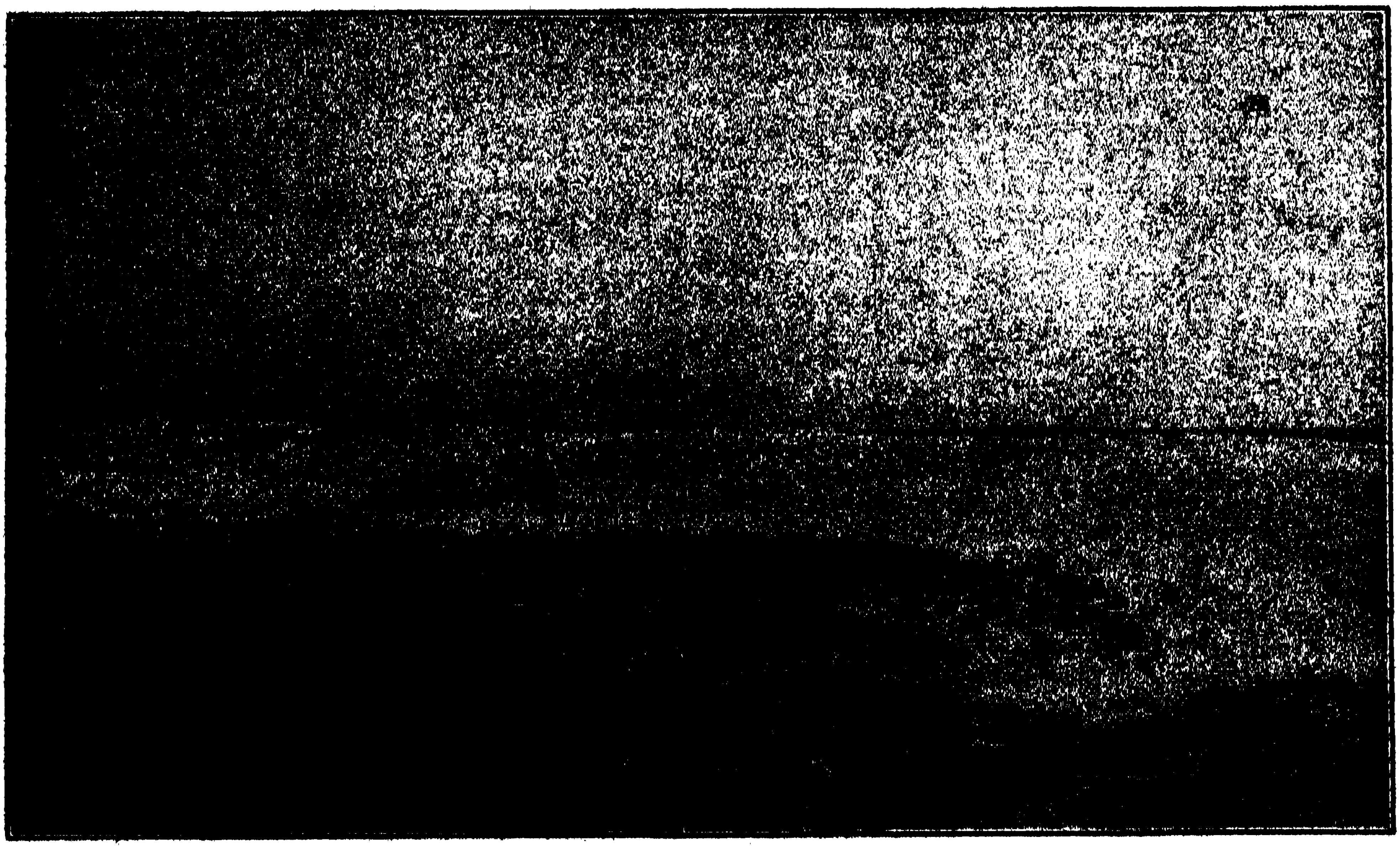
A REGION where no green things grow is the popular conception of a desert, and, with limitations and modifications, this definition is correct. Aside from man-made deserts—and man may devastate by his works of peace as well as by those of war—deserts are generally due to scanty rainfall. Such are the true deserts of the southwestern United States and the great African and Asiatic deserts. They may, however, owe their origin, even in regions of sufficient rainfall, to certain conditions of the ground. A plain of bare rock destitute of cracks is, necessarily, a desert, and a region of drifting sand takes on desert characters. Where rocks are pounded into sand by wave-action and the sand washed up on a beach and where strong winds bear the sand inland dunes are to be found, and these dunes, even if the rainfall is plentiful, may be classed as semi-deserts.

Comparisons, although said to be odious, are often interesting, so it may be well to compare these two regions of desert and semi-desert, taking for concrete examples the true desert of southern Arizona and a sand-dune region not far north of Cape Ann on the Massachusetts coast.

At the outset it must be admitted that there is a charm to both the true desert and the semi-desert. At first sight both appear to be dreary and desolate places and are frankly so considered by many. In the case of the naturalist their charm is easily explained, for each region abounds in peculiar plant and animal life and their general formation is interesting. But the naturalist is perhaps not a fair



SAND DUNES IN MASSACHUSETTS

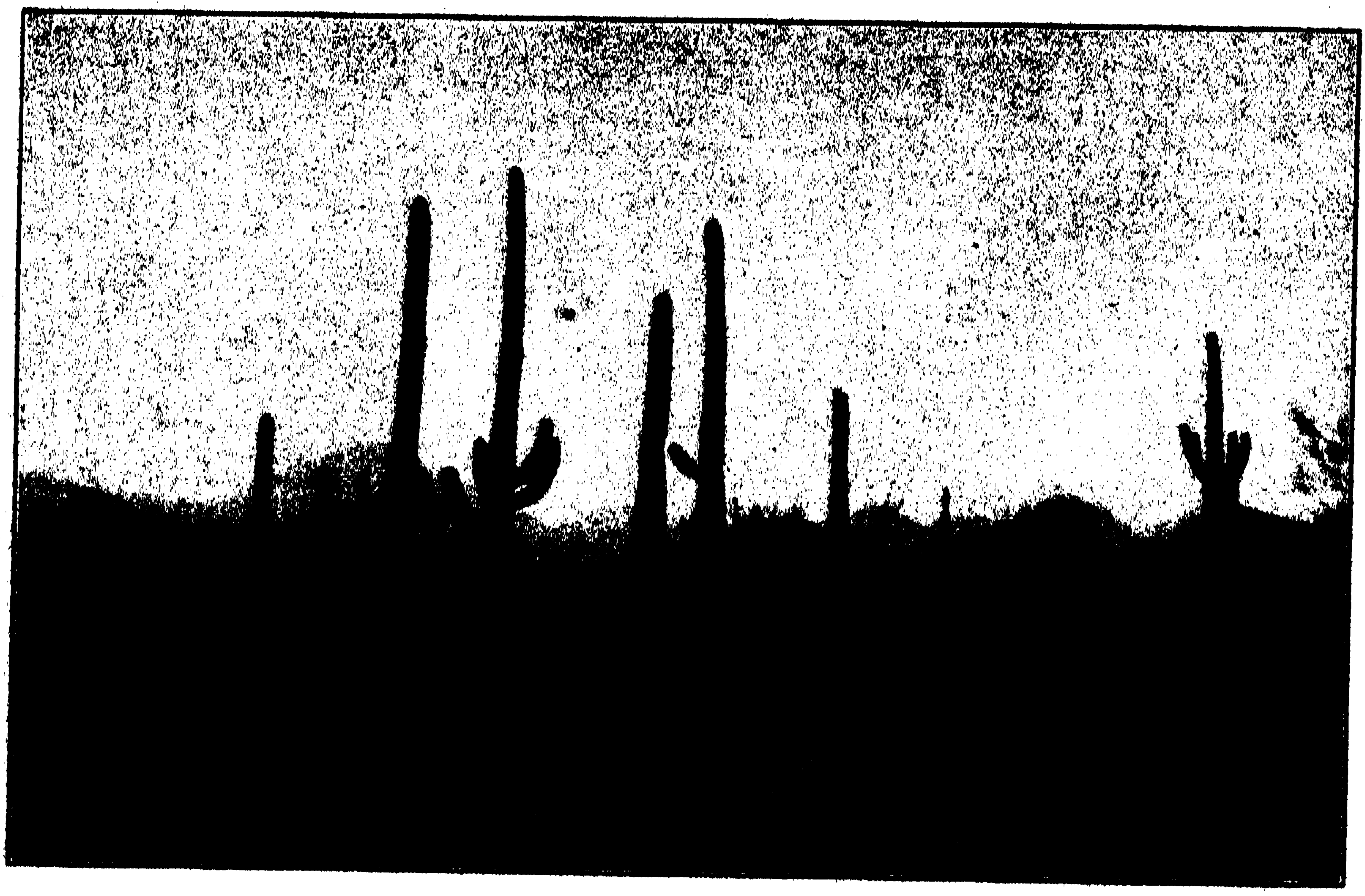


SAND DUNES AT IPSWICH, MASSACHUSETTS

judge of their charm, for all regions of the earth unspoiled by man have for him a perennial charm, and he often experiences all the thrills of an explorer even in familiar and commonplace regions. Artists find in the desert and the semi-desert attractive subjects for their brush and poets for their pen, but this love of desert regions is not limited to any class—it is found among all classes.

To what is this charm due? It is evident that some of the charm may be found in the setting. In the regions of the semi-desert the constantly changing sea and marshes set them about, and the white dunes are as pearls in this turquoise and emerald setting. The immense deserts of southern Arizona are girt about by mountains whose jagged outlines—true *sierras*, saw-shaped—stand up on all sides against the cloudless blue vault of heaven. Just as the colors of the setting of sea and of marsh are constantly changing, so the colors of the mountain setting in the true desert are ever changing. It is impossible to exaggerate the variety and brilliancy of coloration in these desert sierras. The clearness of the air adds to the charm and mystery—and there is always a charm in mystery—for mountains ten and twenty or even forty miles away appear at times within a short walk. From brown and gray they may suddenly change to purple and to flame-color, and, in winter storms, when brief rains fall into the desert sands, the summits of the mountains become brilliantly white with snow.

The setting, then, is one of the explanations of the charm of these two desert regions, but it is not the only one and is, perhaps, of little importance, after all, for when one is in some depression in the midst of the dunes of the seashore or of the true desert and can see naught but sand and desert all about, the charm is still there and is even intensified. To my mind the primeval character of the desert, the absence of all signs of civilization, the very bleakness and desolation itself, the solitude, the mystery—yes, even the grimness which arouses primitive feelings of self-preservation—are all elements which attract and charm. Per-



GIANT CACTI AND CHOLLAS IN THE TUCSON MOUNTAINS

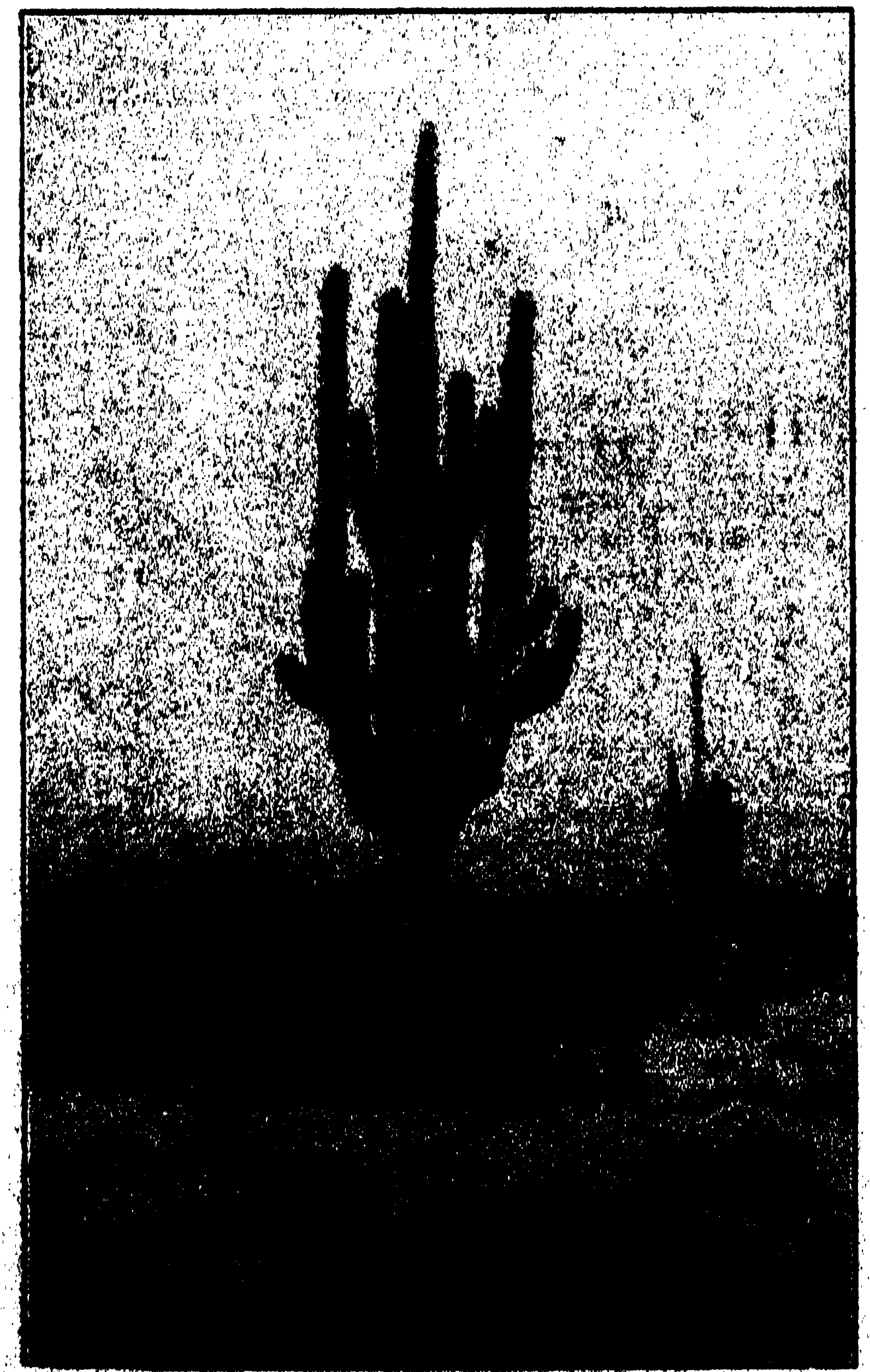
haps long slumbering instincts aroused in these scenes may, unknown to us, be the real source of this charm. But, after all, the charm of the desert can not be explained to those who are insensible to it.

In both the desert and semi-desert the heat of the surface at midday is extreme, but it cools quickly at night. A surface temperature of 172° Fahrenheit has been recorded in Arizona at midday, but the range of variation between day and night temperatures is reduced with every inch of descent below the surface. At six inches, the variation is only 17°, and at ten inches, 2°. No wonder that the numerous desert mice and rats burrow beneath the surface and rest by day, or that the mice and toads in the seashore dunes do the same.

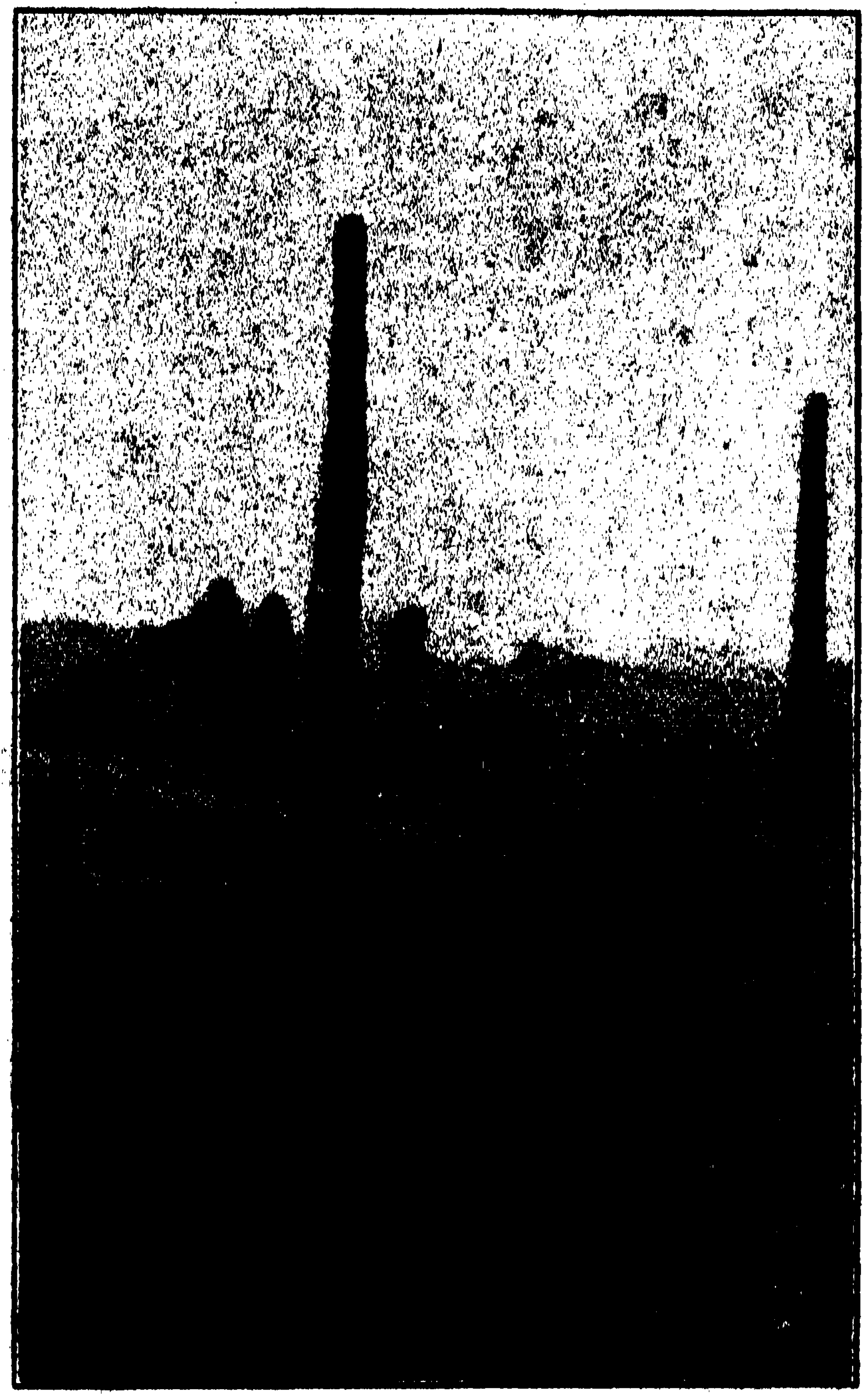
In both the desert and the true desert what is generally deemed protective coloration of various classes of animal life takes on the form of grayness. Brilliant and striking contrasts in coloration often disappear. At the seashore there is a grasshopper which, alighted, is obliterated to sight by reason of its close resemblance to the sand. The male sand dune spider that roams abroad is sandy colored, while the female that stays at home in a dark hole is black. The common or garden toad loses its brown earthy color and becomes gray and sandy in the dunes. The Ipswich sparrow, nesting in the wave-assailed dunes of Sable Island and spending its winters in the dunes along the Atlantic coast, is light and sandy colored—strikingly so when compared with its nearest relative, the Savannah sparrow, from which it probably split off.

In the same way, in the true deserts there are numerous creatures that are desert-colored. Some are pale and sandy, others as buff and reddish as the broken lava amidst which they live. Insects and reptiles, birds and mammals take on these colors. The flocks of desert horned larks nearly disappear when they alight, and the jack rabbit is generally invisible until he runs. To say that these creatures are easily seen when in motion is no argument against protective coloration, for in critical moments they are generally motionless. A downy young gull is easily seen on the seashore when it is moving, but when pursued or waiting to be fed it spreads itself motionless and is obliterated to sight in the sandy waste. Natural selection quickly weeds out those who do not obey this instinct of immobility.

The fact that many creatures are not desert-colored does not disprove the protective theory, for there may be some reason, perhaps in unpleasant secretions or stings, or in superior mentality, as in the case of the crow family, or even in abundant reproduction, which renders this protection unnecessary. One must know not only the present life history of these creatures in every detail, but also their past for many thousands of years before deciding absolutely on these points.



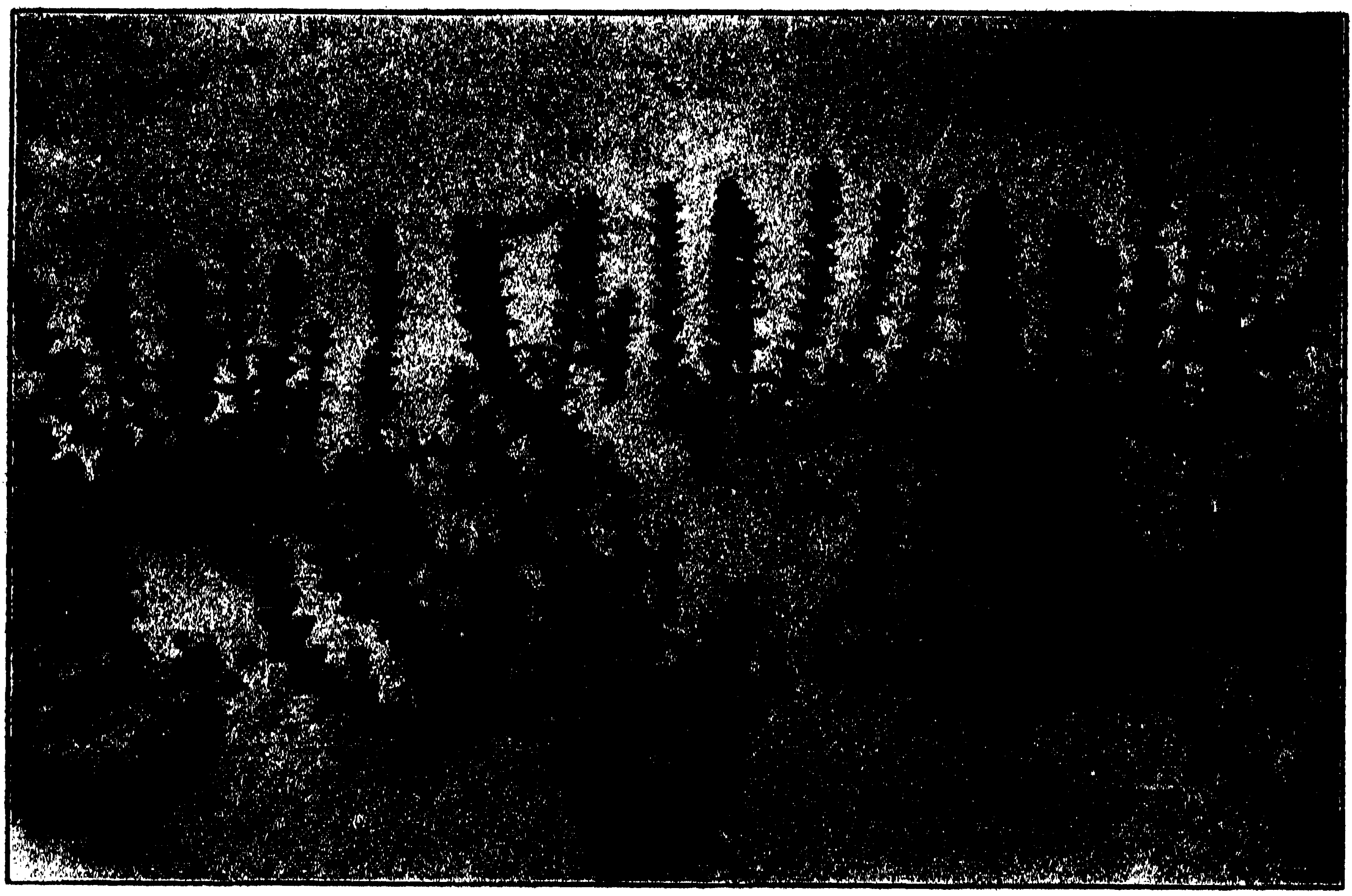
GIANT CACTUS



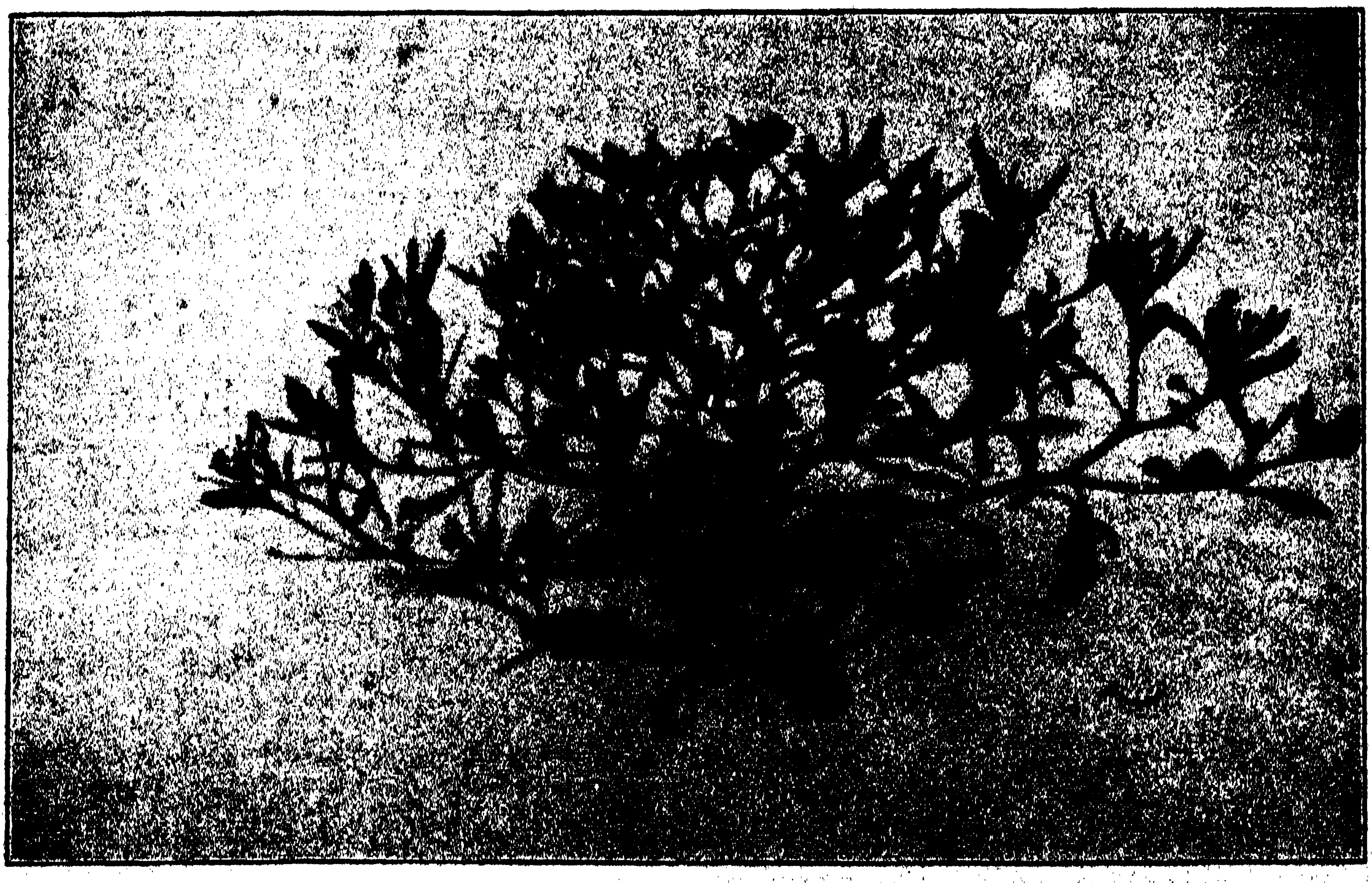
GIANT CACTI

It has been contended, on the other hand, that the desert coloration is merely the result of physical conditions in the desert, a chemical change due to heat and dryness, just as dark pelage and plumage are common in humid regions. Even so, this change affords an opportunity for natural selection to step in and to give those most protectively colored better chances for survival.

But why, it may be asked, should many of the mice be gray like the desert and yet spend the hot and dry days in a cooler and moister climate under ground? Here the difficulty is doubled, for the grayness is not needed for protection at night, and, if the grayness is dependent on heat and dryness, these animals are but little exposed to these



SANDWORT



SEA ROCKET

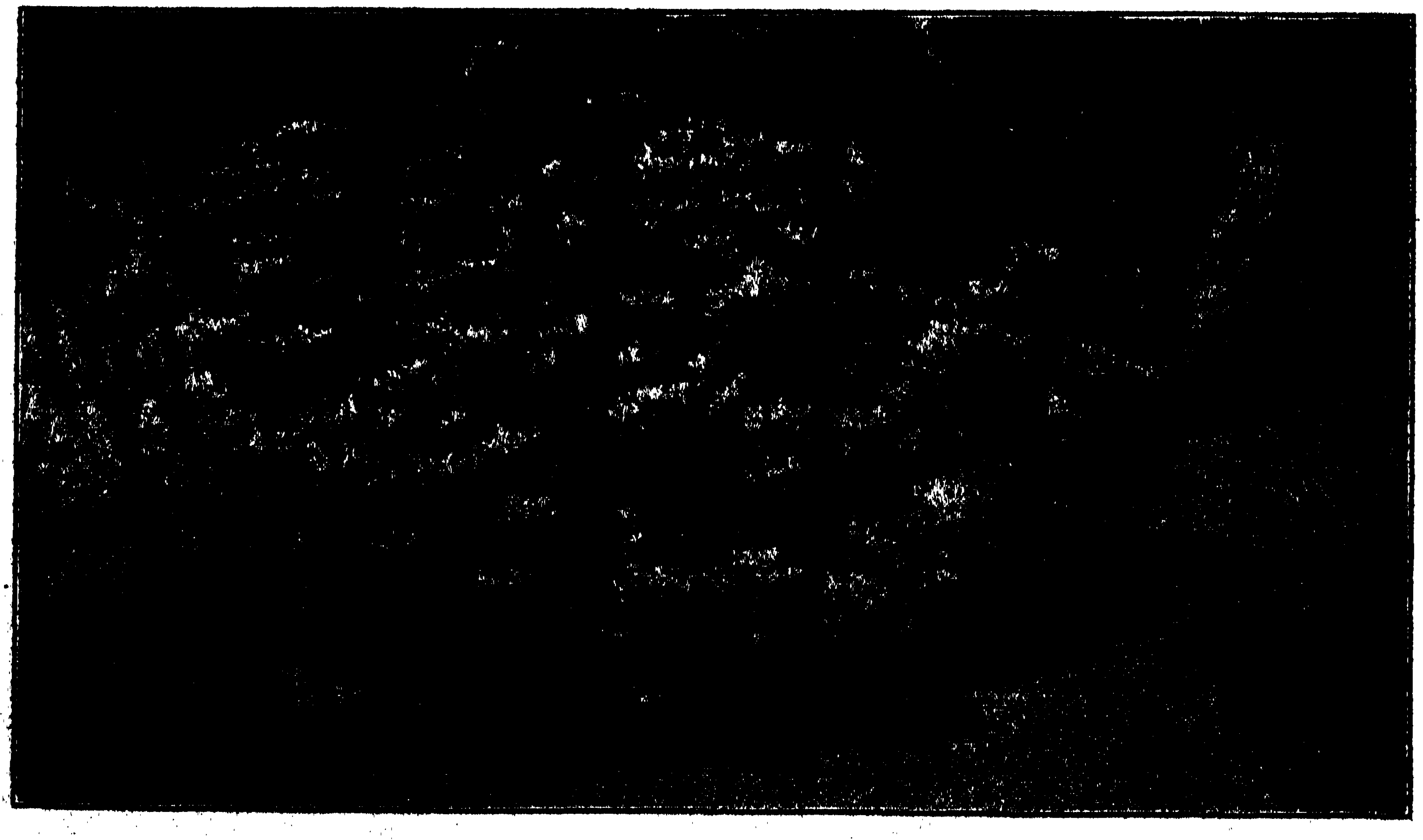
influences. Here, also, a complete knowledge of the life history, past and present, may solve the mystery.

Sand, both in the true and in the semi-desert, is far from a favorable station for plants. Especially is this the case when the surface is constantly shifting, borne along by the wind. Furthermore, rain in falling on sand sinks in almost at once and leaves the surface dry as soon as the storm is over. This dry surface mulch and the poor capillarity of the sand, owing to its comparatively large grains, act favorably, however, in preventing rapid evaporation.

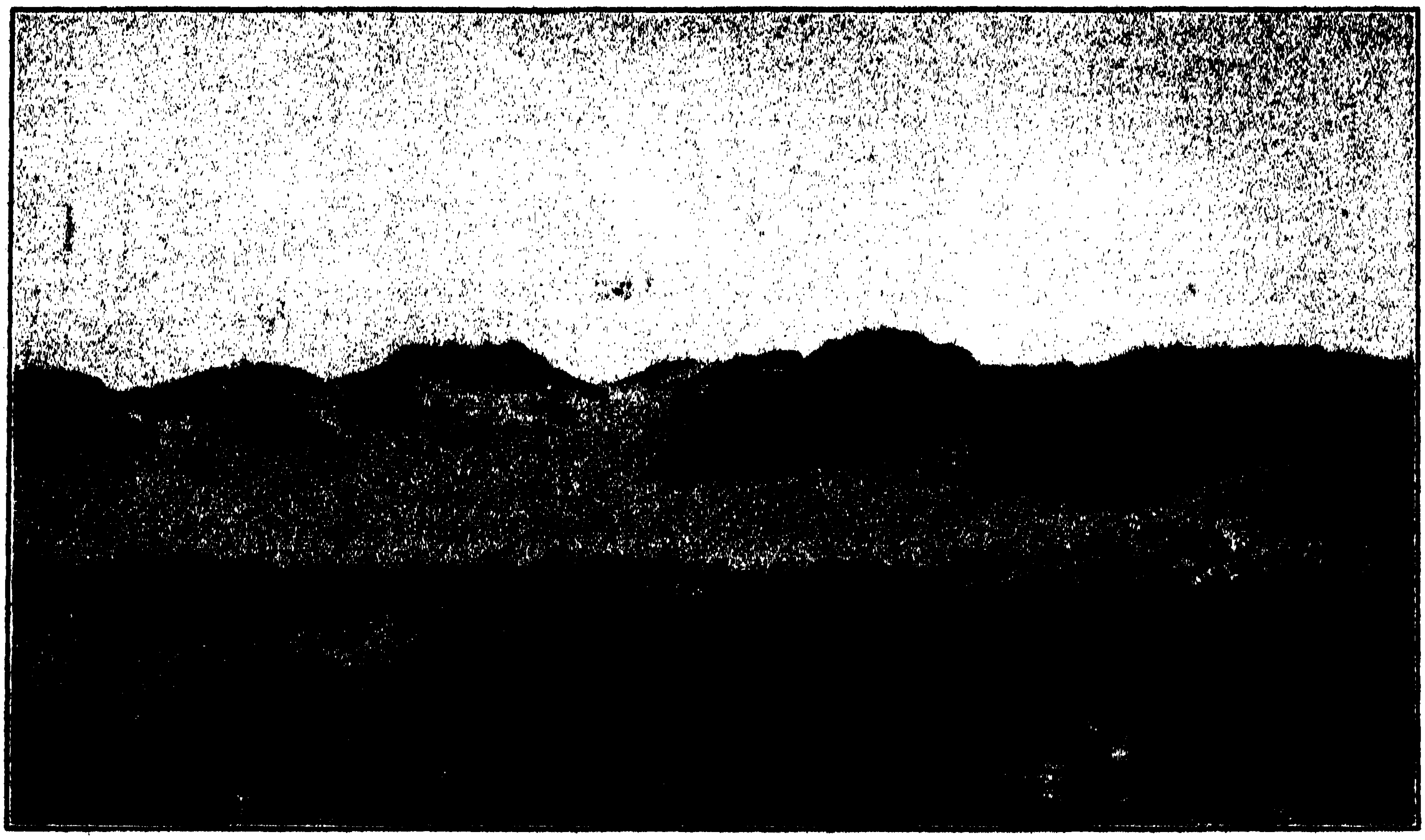
The typical desert plants in order to survive must not waste the scanty water supply by undue evaporation and must store it up for use in long periods of drought. To diminish evaporation, many of them are destitute or nearly destitute of leaves and perform most of their plant reactions by means of the chlorophyl of the stems. Such are the palo verde, the crucifixion thorn and the desert "broom." Others accomplish the same thing by their tough surface-protected leaves as in the creosote bush. A protection of wax or resin or salts or densely matted hairs prevents to a large extent the evaporation of water.

The cacti are typical examples of water-storers. Their succulent stems, swollen to a great size, store up much needed water. The giant cactus—the saguara—which rises to a height of forty feet, stores in its trunk and limbs many gallons of water, while the barrel cactus has been made to yield to the thirsty traveller several quarts of potable fluid.

Most of the desert plants except the annuals are characterized by thorniness, the cacti to a notorious degree, and many of the other plants are thorny, as, for example, the mesquites, cats-claws, ocotillos and yuccas. Plants which lack thorns, like the creosote bush, are often distasteful to browsing animals. At first sight, therefore, it would appear that thorns are protective developments of desert plants, without which they would be exterminated by browsing and gnawing animals. This view is opposed, however, by some who show that thorns are the result of the physical and chemi-



DUSTY MILLER



SAND DUNES

cal influences of the desert, and that plants grown in a dry atmosphere tend to produce thorns, while cultivation in a damp atmosphere discourages them. They admit that the thorns may act as a defence, but believe that this protection is merely incidental or, it may be said, accidental. Now it may often happen both in nature and in the inventions of man that what was at first merely incidental and apparently unimportant becomes of prime importance. However this may be, it is plain that thorns once started would be elaborated by natural selection as a defense. If one has seen a starving cow with a branch of cholla cactus attached to its muzzle by wicked barbed thorns, one can easily understand why the cholla flourishes in the desert and almost never shows signs of injury by rodents or browsers. It is said that the spineless cactus, a form of prickly pear without the prickles, soon ceases to exist in cattle ranges.

Deserts are almost always pictured as regions of terrible and grim struggle for existence, but the animals are necessarily as accustomed and fitted to their surroundings as are those of other regions, and they doubtless lead as happy and as carefree an existence as do the creatures of humid regions. Unlike foolish man they do not suffer by their memories of the past nor worry about the future. In fact, some deserts seem to be particularly adapted to rodents, for the number of species and individuals in the deserts have been found to be greater than in the adjoining forest-clad mountains, where existence would seem to be much easier. In the same way, the polar regions are pictured as regions of terrible struggle, but there is no happier race of man nor one more completely adapted to its surroundings than is the race of Eskimo. It is difficult to put ourself in the other fellow's place, and much unnecessary sympathy is often wasted.

To one unfamiliar with the true desert of southern Arizona this has a bizarre and weird appearance, not entirely of this world. The cacti are strange and uncanny, yet even here we may find likenesses in the semi-deserts of the eastern coast, for the factors of succulence or water-storage, of thorniness and of diminution in the size of the leaves are all present. Thus, the sea-rocket grows in abundance on the dry stretches of sand of the upper beach and resembles the cacti in storing water in its swollen joints. The saltwort not only stores water in its leaves, but their points are sharp and prickly. The Hudsonia (inappropriately called poverty grass, for it bears a wealth of golden blossoms) avoids loss of water from its leaves by their reduction to minute downy scales. The sage brush of the true desert with its leaves covered with downy hairs to prevent evaporation is represented in the semi-desert by a plant of the same family, the dusty miller.

In both regions long-rooted plants have great advantages, and beach grass, seaside spurge, Hudsonia and beach pea thrive for this reason on the tops of the dunes at the seashore, while in the true desert, the mesquites, cats-claw and palo verde, belonging to the same family as the beach pea, also enjoy the advantages of long roots.

Different in many ways, therefore, as are the semi-deserts and the deserts, they have on examination various points in common and both exert a charm that grows with knowledge and familiarity.

TWO NOTED MINERAL COLLECTIONS[1]

By Dr. GEORGE P. MERRILL
U. S. NATIONAL MUSEUM

DURING the summer of 1926 there passed over to the majority two of America's most noted collectors of minerals, and the results of their years of work and recreation have fallen into other hands. It will be of interest to devote a few pages to a history and description of these men and the collections they assembled, in view of the fact that both of the latter have become, one by bequest, and one by donation of a son and heir, the property of the United States National Museum in Washington.

THE CANFIELD COLLECTION

This is, in part, one of the oldest private collections in America, its nucleus having been formed by Mahlon Dickerson, of Dover, New Jersey, who began collecting in the early part of the nineteenth century. The collection apparently passed to his nephew, Frederick Canfield, Sr., and to it were added many fine specimens collected at Franklin Furnace, Stirling Hill, and neighboring localities between the years 1840 and 1866. This collection, comprising some 1,600 specimens, was arranged in cases in the parlor of the family mansion near Dover, where it remained undisturbed until it was packed for shipment to the National Museum at Washington in the summer of 1926. (See Fig. 1.) Made at a time when few American localities had been discovered, the collection was a general one, comprising many specimens from the classic European localities. The outstanding materials, however, are those collected at Franklin Furnace and vicinity previous to 1860. These include large crystal groups, some of them upward of one hundred pounds in weight, of jeffersonite, franklinite, gahnite and garnet and many fine masses of calamite, zincite, etc., all of which are probably the finest of their kind. There are also exceptionally fine crystallized chalcocites from Bristol, Connecticut, and pyromorphites from the Wheatley mines of Pennsylvania.

Frederick A. Canfield, son of the Frederick Canfield mentioned above, who inherited the collection, preferred to leave the older exhibit intact and begin a new one of his own. This latter at the time of his death totaled some 7,500 specimens and, together with that of his father, comprises his bequest to the National Museum.

Educated at Rutgers and Columbia Universities as a mining engineer and geologist, F. A. Canfield found in the practice of his profession an opportunity for travel and acquisition of his specimens at first hand. Perhaps the most noteworthy of the minerals obtained in this way were the Bolivian silver compounds which he brought back in 1887. Among these are exceptionally fine groups of pyrargyrites, and one single mass of argyrodite, a mineral consisting largely of the very rare element germanium, the largest piece of this mineral known. A large dodecahedral crystal of the same is also worthy of note. It was in this lot of material that Professor S. A. Penfield found in 1894 a new mineral, a tin analogue of argyrodite, to which the name *canfieldite* was given. Another specimen of note is a great cleavage mass of Brazilian topaz weighing ninety-five pounds, thought to be the largest of those recently brought to this country.

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[1] The details given in this paper were furnished by Earl V. Shannon and William F. Foshag, who superintended the packing of the collections for removal to Washington.

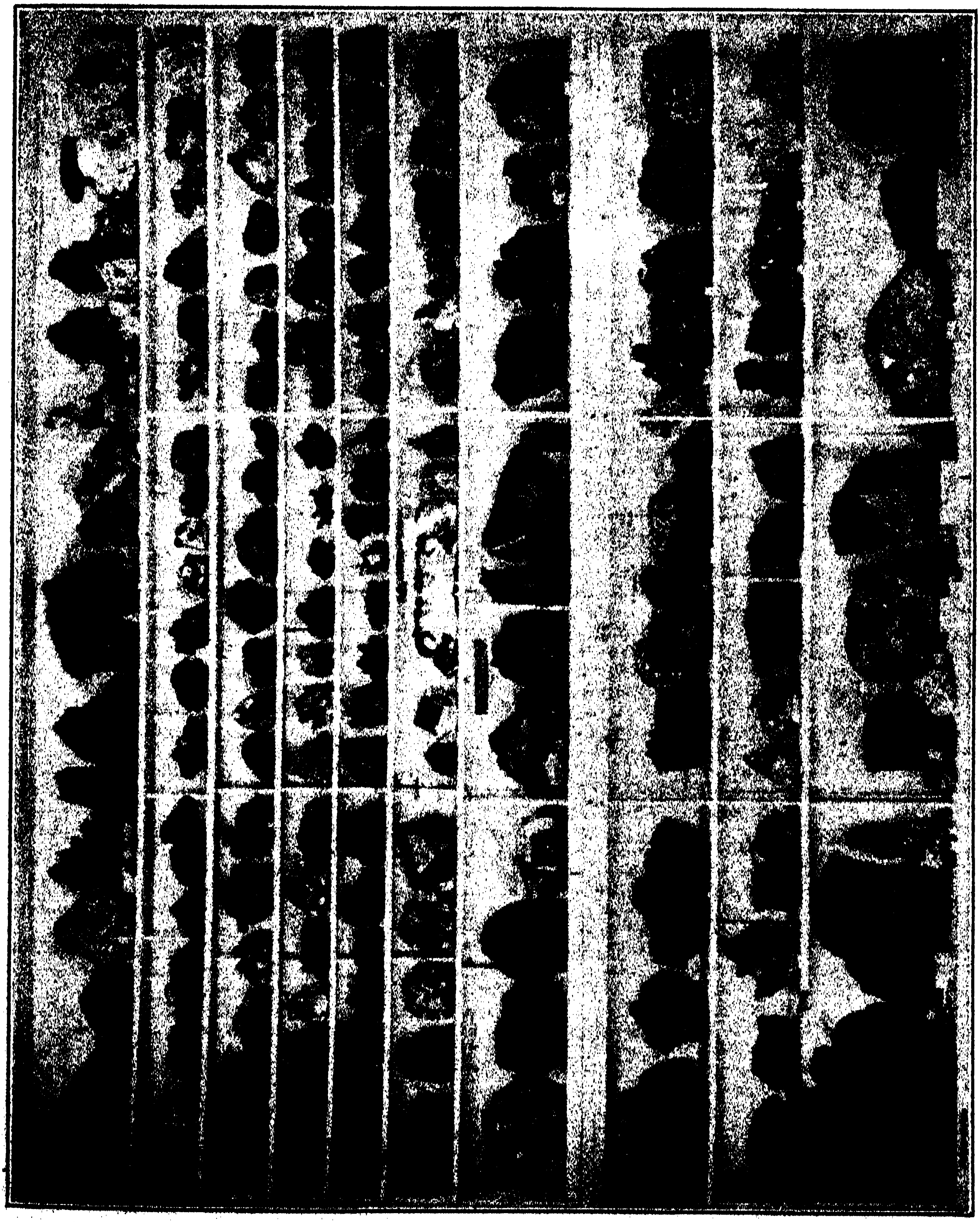

FIG. 1. PART OF THE COLLECTION OF FREDERICK CANFIELD, SENIOR, MADE PRIOR TO 1866

Possessed of a modest income, Mr. Canfield subsidized workmen in the railway tunnels and stone quarries of northern New Jersey to gather for him the choicest specimens as the work progressed, and his professional connection with the mines at Franklin Furnace enabled him to keep pace with the new and rare minerals constantly found there. Although he acquired a considerable stock of duplicate material he very rarely released a specimen once it had found its way into the house. It was his endeavor so far as practicable to continually improve the quality of his collection by replacing inferior with better specimens of the same mineral as opportunity offered. Occasionally a newly described mineral or a new find would apparently take his fancy and he would obtain a complete suite if such were available. Such suites of benitoite, neptunite, bixbyite, etc., found in the collection are now well-nigh priceless. Many of the specimens owe much of their beauty and value to the long hours of painstaking work which he spent in removing the matrix from crystal groups.

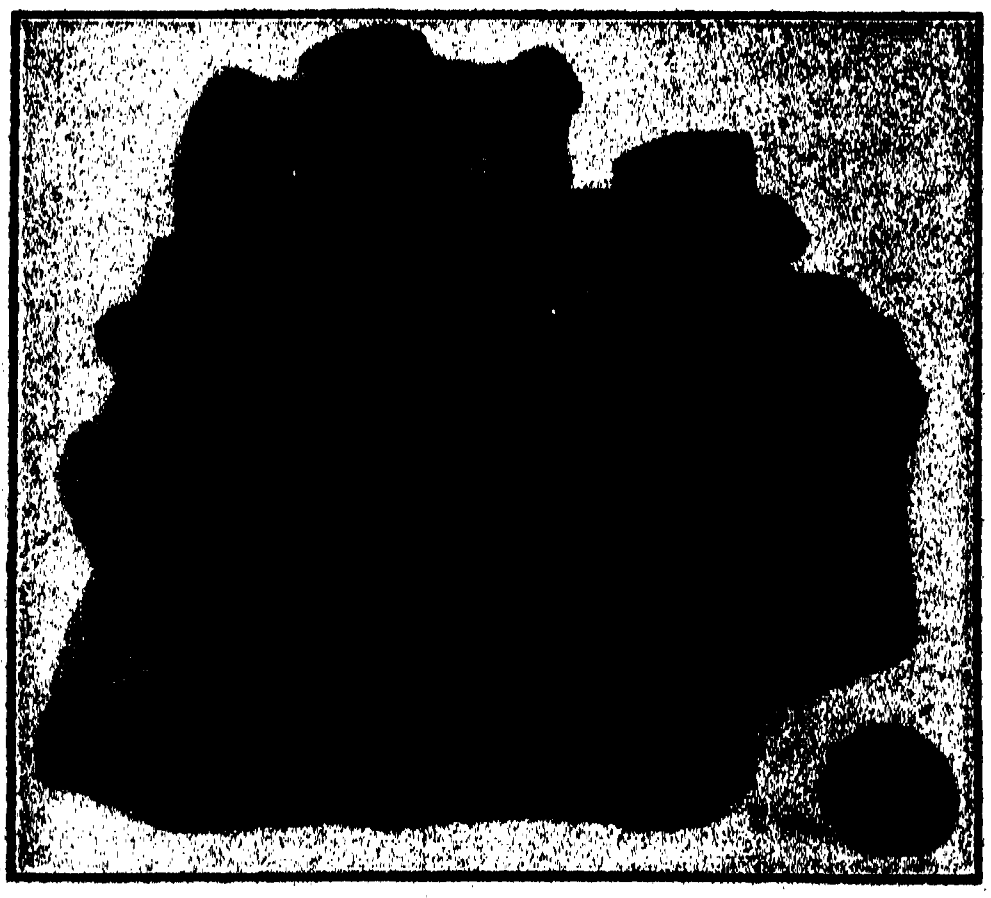

FIG. 2. GARNET CRYSTAL
ABOUT FIVE INCHES IN DIAMETER, WITH ATTACHED PYROXENE

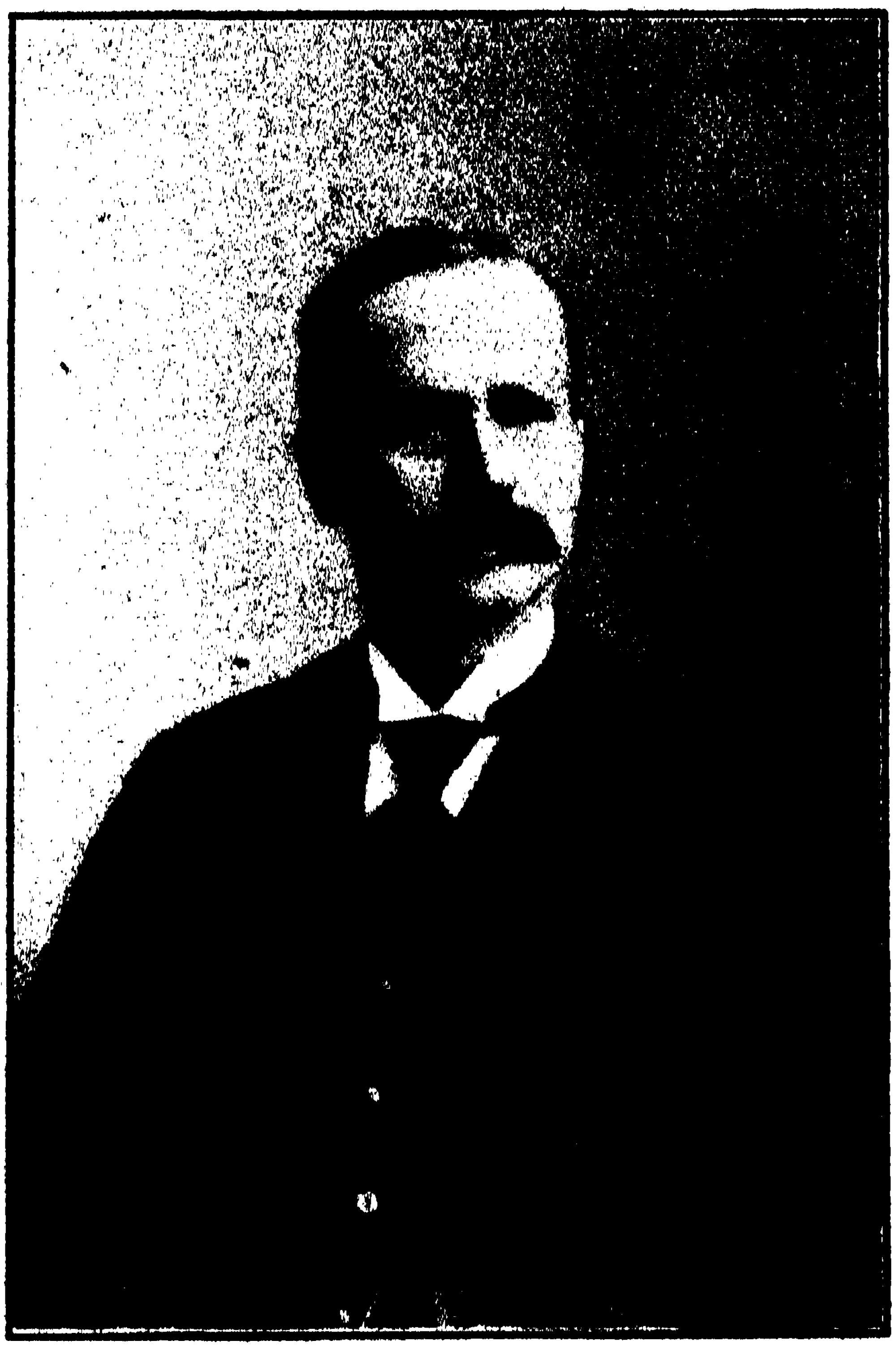

FIG. 3. MR. F. A. CANFIELD

Mr. Canfield never married, but after the death of his mother lived in his picturesque house situated in a grove of pines on the hilltop, with no companions other than an elderly housekeeper and a gardener. His time was largely given up to his hobbies—first, his minerals, second, coins, of which he had a very valuable assemblage, and third, the study of his family history and genealogy. The mineral collection was housed in beautiful oak and mahogany cabinets, the specimens neatly labeled, catalogued and numbered.

Though scientifically trained, Mr. Canfield seemed content merely to accumulate, doing a minimum amount of research work, his total bibliography including only six titles. He was coauthor with Hillebrand and Schaller in the description of the mineral *mosesite*, and the type specimen of that mineral is in his collection. An interesting pamphlet which he published within a few years of his death was a compilation giving the final disposition of all the notable collections of minerals.

Mr. Canfield died on July 3, 1926, and in his will bequeathed the mineral collection, together with an endowment of $50,000 for its upkeep, to the Smithsonian Institution. As with the next to be described the collection is now deposited in the National Museum.

The Roebling Collection

The career of Colonel Washington A. Roebling has of late been made pretty generally known to the newspaper reading public. He was born in Saxonburg, Pennsylvania, the son of John A. and Johanna Herting Roebling. His father, a native of Prussia, was a civil engineer trained in the Royal Polytechnic School of Berlin and for a time engineer for the government of Prussia. Among the projects he undertook in America was the building of a suspension bridge across the East River, New York. Through an accident he was badly injured and died of tetanus before even the plans had been fully drawn up. It fell to the son, Washington A. Roebling, then a man of thirty-two years, to build what was destined to be one of the engineering wonders of the age—the Brooklyn Bridge. This great task received his personal supervision and during the sinking of the caissons for the foundations of the structure he spent many hours under such atmospheric pressures as to threaten his life and to permanently injure his health, making it necessary for him to direct the entire work, scarcely a feature of which did not present new and untried problems, from the sick room. In seeking relaxation from the strain on a weakened physique he turned his attention to the collecting of minerals. Unable to undergo the physical discomforts of travel and active work in the field, but fortunately endowed with the necessary financial means, he did a large share of his collecting by correspondence and

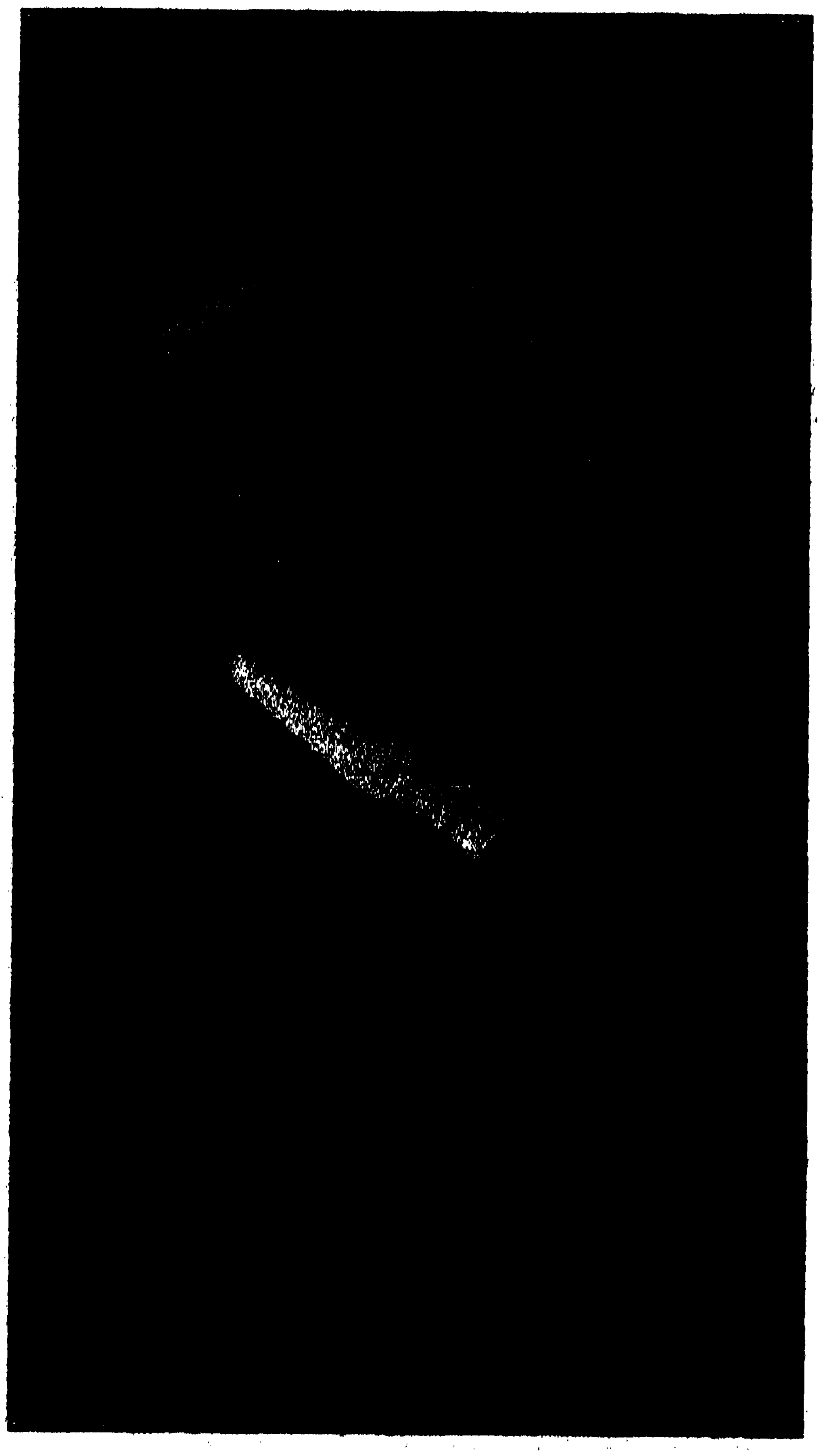

FIG. 5. COLONEL WASHINGTON A. ROEBLING

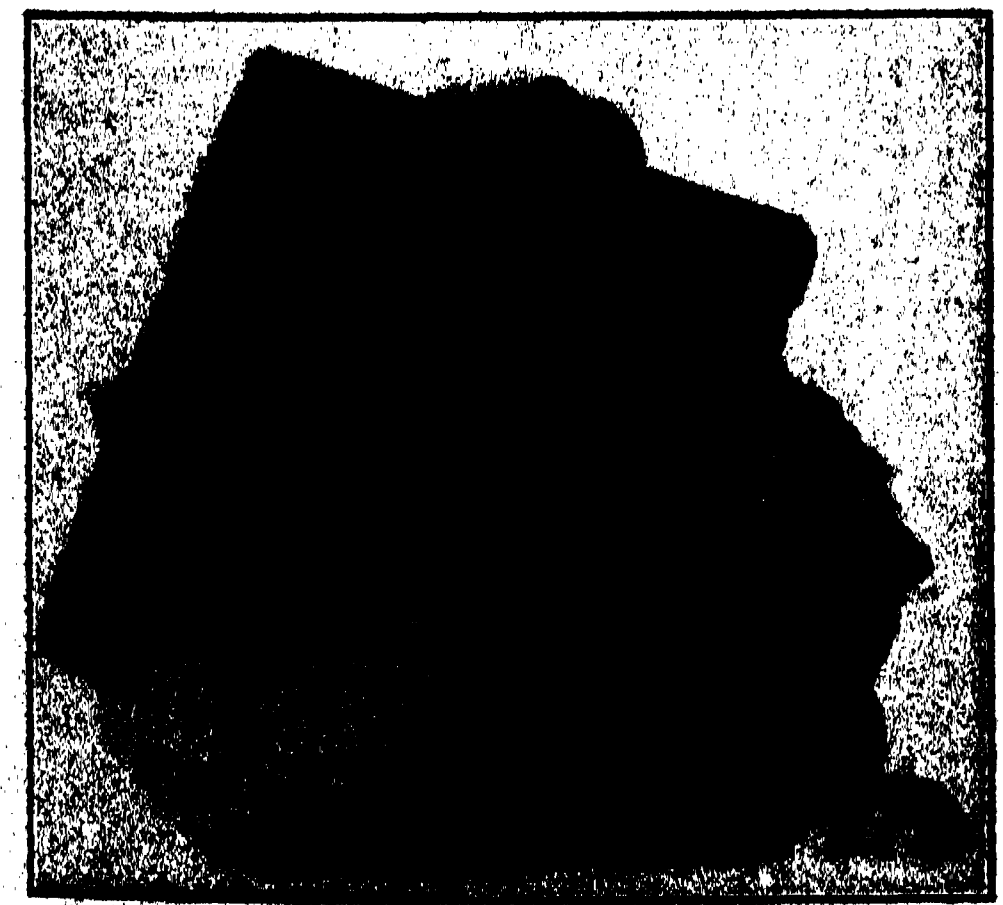

FIG. 4. DYSLUITE CRYSTAL
ABOUT SIX INCHES IN DIAMETER

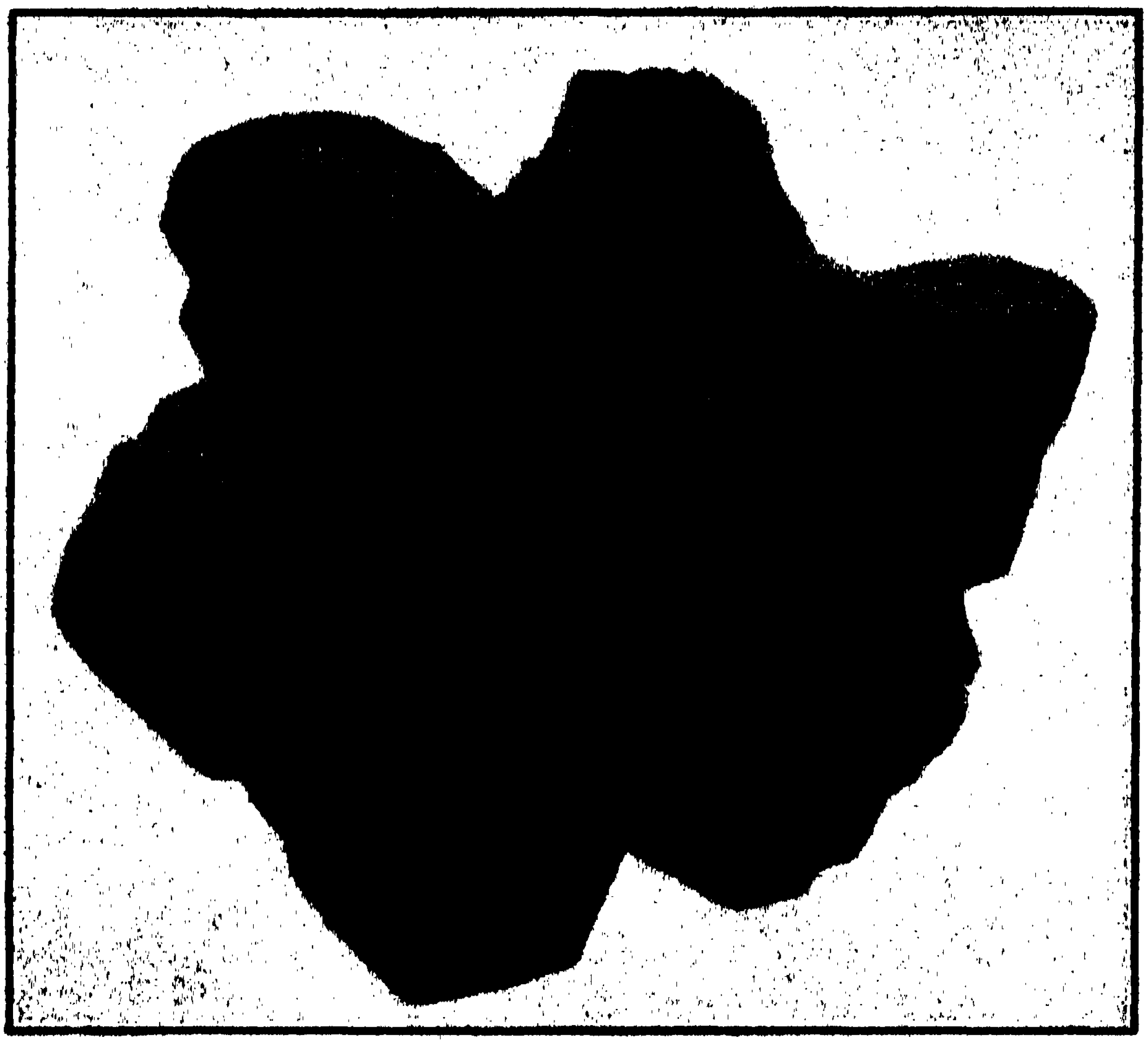

FIG. 6. A CHRYSOBERYL TRILLING
NATURAL SIZE, FROM THE ROEBLING COLLECTION

there is probably not a dealer or collector of importance in the country that has not in his files one or more letters written in the fine, almost womanly hand for which the Colonel was noted. He sought not merely the beautifully developed specimens but those that were rare—indeed his aim was to secure a representative of every known mineral, however insignificant and uninteresting in appearance it may have been.

While Colonel Roebling was not himself a man of research, he fully appreciated the work of those that were, and his choicest specimens were always accessible to authentic workers. Many mineralogists were frequent beneficiaries from his willingness to help through loan of specimens or by direct gift. With the National Museum he had been for years on particularly friendly terms of cooperation, a fact that doubtless was of influence in deciding the final disposition of his collection. The specimens were never catalogued but were completely labeled in his own hand, often with amusing annotations and personal reflections. But about a dozen of the well-defined species are wanting, and many old and obscure varieties may be found that are lacking in other collections—even the humblest having been secured wherever possible. It is in its completeness that its scientific value lies. Some of the more notable of the specimens have, since his death, received attention in the columns of the newspapers, but the matter will bear repetition here.

Apatite: An extraordinary deep, rich purple crystal from Auburn, Maine, measuring 38 x 43 mm in the horizontal direction and 30 mm in the vertical direction, and weighing slightly over 100 grams. So unusual is this crystal in respect to size, color and crystal development that it was deemed worthy of description by W. E. Ford in the *American Journal of Science* for September, 1917.

Beryl: A considerable number of examples representing many varieties and localities. Three from Brazil are especially fine; one weighing about a kilogram, of a light greenish yellow color with sharp hexagonal crystal boundaries, clear and flawless; one blue-green of about the same weight; and one light

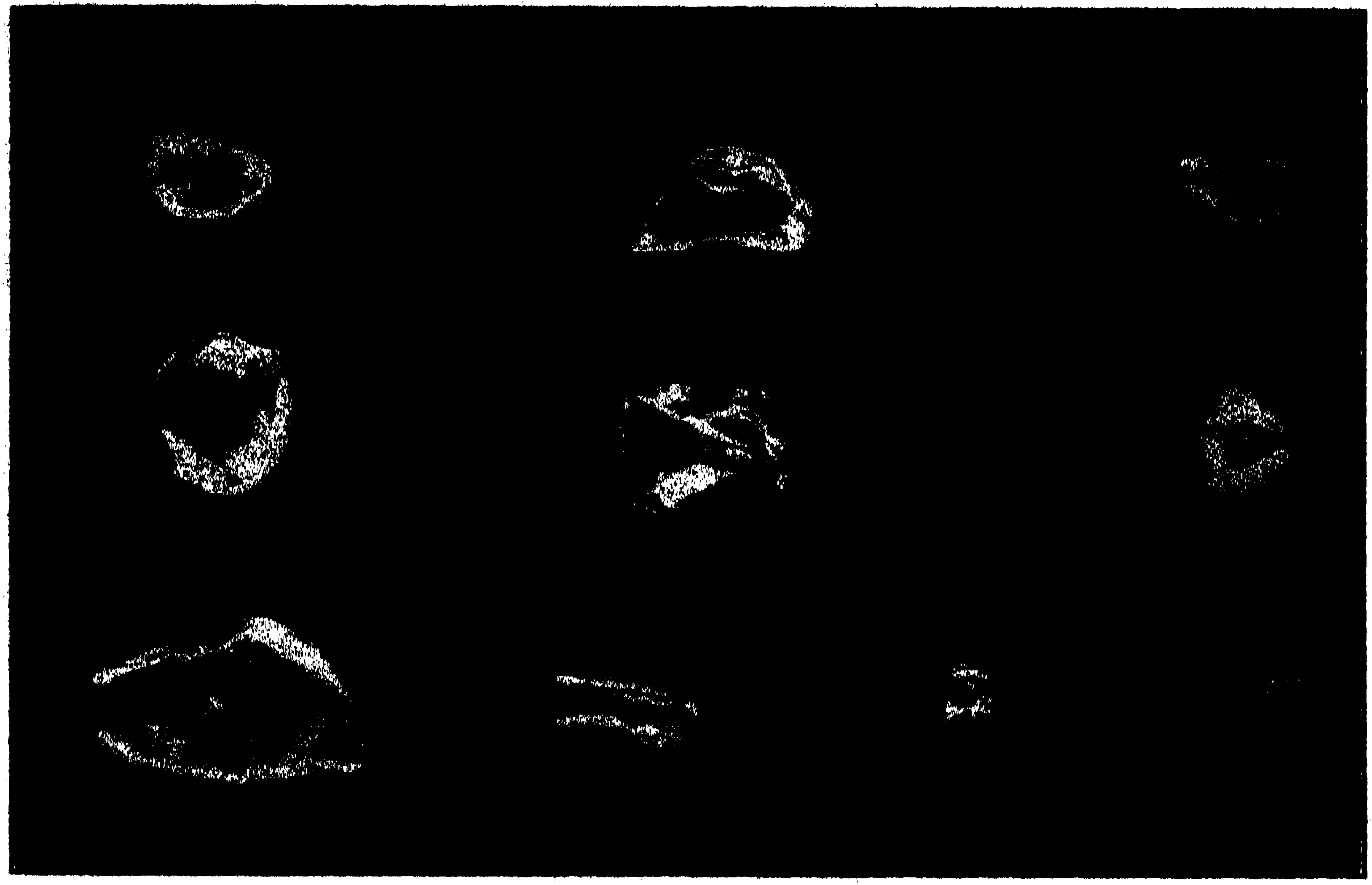

FIG. 7. ARKANSAS DIAMONDS IN THE ROEBLING COLLECTION

blue, with very good crystallographic development of the pyramid. The alkali beryls from Madagascar and California are also represented.

Chrysoberyl: Two fine trillings, uncut. Have the form of a six-rayed star (see fig. 6), are sharp in their crystal development and of a light green color. The largest is about 74 mm in diameter. There are also representatives of the variety alexandrite, one cut gem from Ceylon weighing 16.7 carats, and two uncut crystals from the Urals.

Diamond: Represented by a remarkably well-developed black crystal in the form of a perfect cube some 15 mm in diameter, with dodecahedral and octahedral forms on its corners and edges. Weight 64 carats. There is also the series of ten from Pike County, Arkansas,[2] shown in figure 7.

Euclase: A large light greenish-yellow fragment, showing some crystal faces, clear and flawless throughout, weighing 128 grams, from Brazil—a unique piece; also a light blue cut stone of fine quality, weighing nearly 4 carats.

Kunzite: Represented by a flat crystal some 30 cm in length, 7 cm in width and 2 cm in thickness, as well as several smaller forms.

Malachite: A beautiful large botryoidal mass some 15 x 30 cm in diameter is interesting for bearing the label, "Brought from Russia about 1874 by the Grand Duke Alexis and given by him to Henry A. Ward, of Rochester, for a mounted buffalo head."

Opal: The opal was evidently a favorite with Colonel Roebling and the mineral is represented by a score or more pieces of all weights. The so-called black opal alone is represented by four fine specimens, one of which is the monster piece 10.5 cm x 7.5 cm x 5.5 cm found in 1917, still uncut and weighing 2,665 carats or 18.6 avoirdupois ounces.

Peridot: A fine clear cut stone some

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[2] For detailed description of these and mode of occurrence see "Diamond-bearing Peridotite in Pike County, Arkansas," Bull. U. S. Geol. Survey 735, 1923, pp. 279–322, by Hugh D. Miser and Clarence S. Ross; *Economic Geology*, Vol. 17, Dec., 1922; or reprinted in Smithsonian Report 1923, pp. 261–272, Publication 2768.

50 x 47 x 16 millimeters, weighing 310 carats, from Isle of St. John, in the Red Sea.

Phenacite: There are several very fine examples of this mineral from Brazil, one large single crystal being 58 mm in diameter.

Roeblingite: This mineral was named in honor of Colonel Roebling. It is very unusual in composition, being the only mineral known to contain any sulphite. It always occurs massive and has been found only at Franklin Furnace, New Jersey.

Topaz: This mineral is well represented both in the cut (gem) and the crystal forms. Three amber-colored, long, prismatic crystals, terminated by pyramids, the longest measuring 20 cm, are from Brazil. There is also a fine group of the Siberian blue topazes and one cut stone weighing 397.9 carats and measuring 39 x 36 x 33 mm, a beautiful cut stone of a rich wine-yellow color weighing 93.6 carats and measuring 34 x 31 x 15 mm; and a cleavage cross-section of nearly colorless crystal from Brazil, weighing 45 pounds.

Tourmaline: Of particular merit is a group of two large pink Mesa Grandes tourmalines perched on a base of quartz crystals. It is stated to be one of the finest and best that California has produced. There are also isolated crystals and cross-sections, showing zonal coloring, from California, Madagascar and other localities.

Many others of the minerals while less showy are exceptionally fine. There are, for instance, good crystals of delafossite, an oxide of copper and iron; a perfect crystal of paramelaconite; an exceptionally fine connellite; one of the few known crystals of jeremejevite; a fine group of magnesioferrite crystals from Vesuvius; native crystals of antimony, and many others. The collection of Langban minerals, perhaps the greatest mineral locality in the world for unique minerals, is said to be unrivaled in America.

Mr. John A. Roebling, recognizing the value of the collection for scientific purposes, has, in memory of his father, presented it to the Smithsonian Institution with an endowment of $150,000, the income from which is to be used in its preservation and for the acquisition of new material that its present relative standing may be maintained.

It will perhaps be well to add that the title *Colonel* as applied to Mr. Roebling was not an empty honor. He promptly enlisted on the outbreak of the Civil War, served with merit until 1865, when he resigned to assist his father in the construction of the Cincinnati-Covington bridge over the Ohio River. The work of his after-life is too well known to need further reference here.

The two gifts above described with their accompanying endowments place the National collections on a par with those of the great museums of the world, and students and workers in mineralogy the country over are to be congratulated that, instead of being sold and distributed, they are to be retained where they will be cared for and accessible to all properly accredited workers as well as the visitor interested only in display.

LINKS WITH ASIA BEFORE THE MOUNTAINS BROUGHT ARIDITY TO THE WESTERN UNITED STATES

By Professor EDWARD W. BERRY
THE JOHNS HOPKINS UNIVERSITY

WHEN the veteran American botanist Asa Gray made his first western trip in 1872 he chose as the topic for his presidential address to the American Association for the Advancement of Science assembled at Dubuque, Iowa, the relations between the floras of North America and Asia, and explained their broader history in a masterly way by an appeal to the geological record—then little known.

The past half century has witnessed a most remarkable increase in our knowledge of the living floras concerned and an even greater increase in our knowledge of their ancestors, but has not greatly altered the outlines of Asa Gray's sketch. At the present time the two richest temperate floras in the world are those of eastern North America and eastern Asia and the remarkable feature of these two widely separated regions is the number of closely related forms that occur in both. If these were merely representatives of widespread genera such as alders or birches or bayberries it would perhaps be less remarkable, but when they include a large number of forms found nowhere else, such as magnolias, hickories, gums, sassafras, tulip trees, etc., it is worth the effort to arrive at an explanation.

There are probably more genera in the Asiatic region, and this is partially explained by its proximity to the great tropical region of southeastern Asia, and the more numerous ranges and greater heights of the mountains in China.

In eastern North America the mountains are relatively low and the mesophytic hardwood region is separated from the wet tropics by the Gulf of Mexico and the arid regions of Texas and northern Mexico. Hence it gets but a few immigrants from the former in the Florida peninsula, and a numerous progeny of arid things such as yuccas, agaves and cacti from the latter, and these last have no representatives in the Asiatic region.

The latter region also has many more species in certain widely distributed genera such as among the maples (Acer), cherries (Prunus), barberries (Berberis), mountain ashes (Sorbus), etc., but falls far behind in service berries (Amelanchier) and thorns (Crataegus).

In general the corresponding trees are larger and more valuable in North America, but nowhere is there such an amazing variety of beautiful flowering small trees and shrubs as in the Chinese region. Other contrasting floral features somewhat aside from the theme of this story are the abundance of the bamboos in eastern Asia and of black oaks and coniferous forests in eastern America.

Among the conifers (including Taxaceae) eastern America has more pines and the exclusive genus Taxodium. Eastern Asia has more larches and spruces, and at least eleven genera not represented in eastern North America, namely Glyptostrobus, Libocedrus, Cupressus, Cunninghamia, Pseudolarix, Keteleeria, Cryptomeria, Fokienia, Cephalotaxus, Podocarpus and Ginkgo.

It would be tedious to attempt an exhaustive comparison and I will therefore mention but a few of the more familiar contrasts. Although there is little disparity in number of species the Asiatic poplars, willows and alders are larger; whereas the American oaks, elms and beeches are larger. There are more figs in the former and more laurels (Lauraceae) in the latter. The roses and their allies, the citrus trees, mangos, chinaberries, ailanthus, Paulownia, the tea family, the persimmons, various genera of the olive family (Forsythia, Syringa, Ligustrum, Jasminum, etc.) are exclusively Asiatic or have a much more varied representation on that continent. I have not mentioned herbaceous plants since these are so sparingly represented in the geological record, but it may be said that along with the contrasts between the two regions there are a large number of identical or closely related species which occur in these two regions and nowhere else, such as arbutus, twin leaf, ginseng, sensitive fern, etc.

If we compare the existing flora of Europe with either the eastern Asiatic or eastern North American we find it to be much poorer in both genera and species. Thus there are few oaks and no magnolias, sassafras, tulip trees, gums—either sweet or sour—walnuts or hickories in present day Europe, and to find a flora at all corresponding with that of eastern North America and eastern Asiatic we have to go back to Pliocene or early Pleistocene Europe, at which time all of the trees mentioned as well as the bald cypress, sequoia, glyptostrobus and many others were present on that continent. Central and Western Asia of the present shows equally marked contrasts and, although little is known of the paleobotanical history of that vast region, what little we do know of its fossil record shows the presence in the past of many familiar trees which are no longer present in that region.

The existing flora of western North America is on the whole similarly contrasted, and its points of resemblance are furnished by what are survivors from other days, such as the sequoias, incense cedar, sycamore, tumion, red bud, California horse-chestnut, etc. All these have a much more restricted distribution in western North America than they had in that region during the later Tertiary, and survive to-day in these restricted areas in what might be called surviving environments, that is, in the humid coastal region of northern California, western Oregon and western Washington, or by retreating to stream valleys as did the western sycamore, or by extinction everywhere except in the Sierra Nevada fog belt as did the big trees.

In other words, the Miocene climate of western North America was more uniformly humid than is the present day climate, and the aridity of certain areas such as the Great Basin is a very modern feature largely conditioned by the climatic changes brought about by the elevation of mountain ranges in comparatively recent times, geologically speaking.

In the western United States there are a number of widely scattered localities from which late Tertiary floras of Miocene age have been recovered. These extend from California eastward to the justly celebrated former lake basin of Florissant, Colorado; and include the Yellowstone Park and various localities in Nevada (Esmeralda formation), Idaho (Payette formation), Oregon (John Day basin), and Washington (Latah basin). These are shown on the accompanying sketch map.

There are many earlier Tertiary floras in this region, notably in the Puget region in Alaska and western Canada and throughout the Rocky Mountain and Great Plains states, to which we must look, in part at least, for the ancestors of these western Miocene

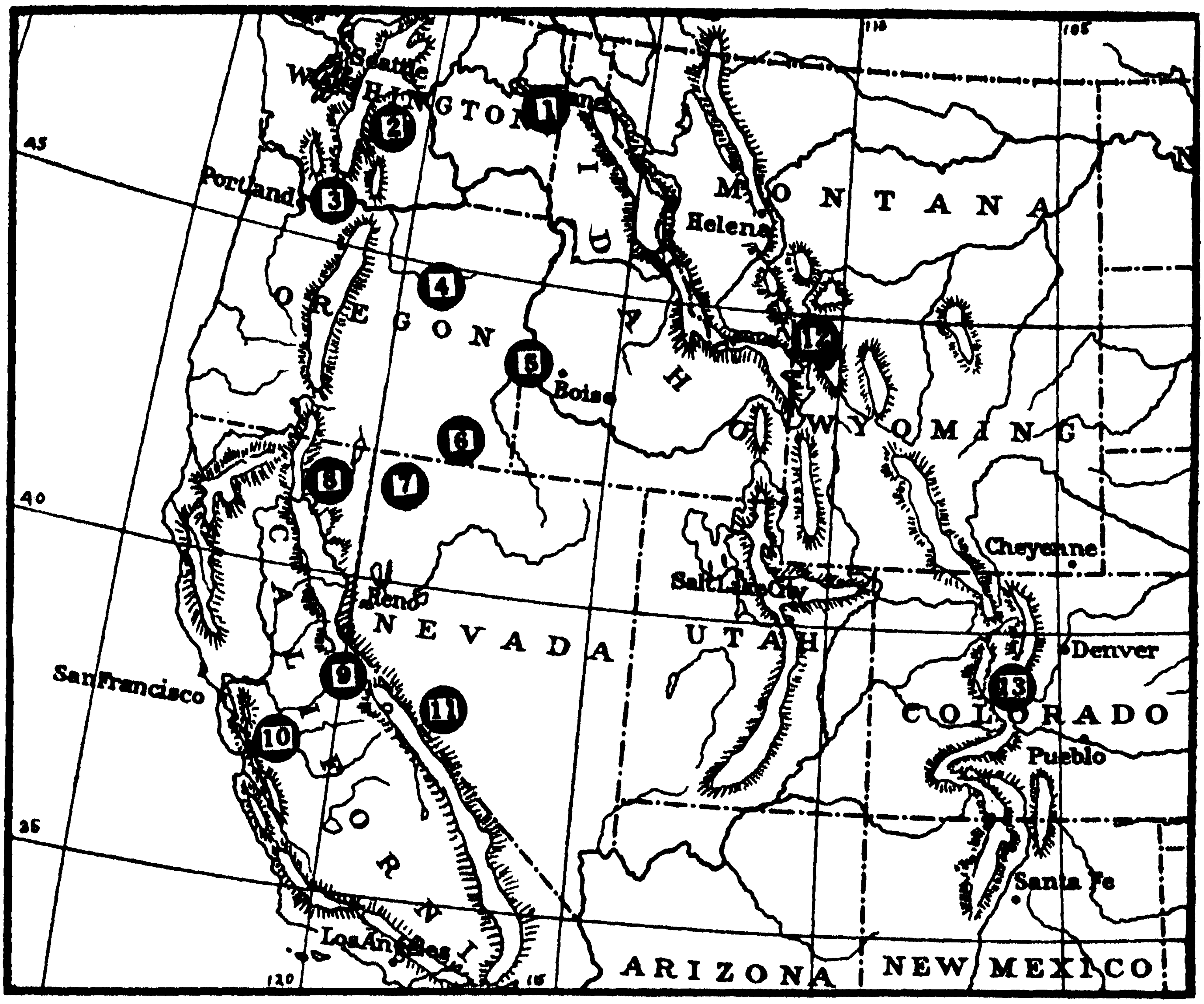

FIG. 1. SKETCH MAP SHOWING PRINCIPAL LOCALITIES FOR MIOCENE PLANTS IN THE WESTERN UNITED STATES.

(1) Latah formation, Washington; (2) Ellensburg formation, Washington; (3) Eagle Creek formation, Oregon and Washington; (4) John Day Basin, Oregon; (5) Payette formation, Idaho; (6) Trout Creek, Oregon; (7) 49 Camp, Nevada; (8) Pitt River, California; (9) Table Mountain, California; (10) San Pablo, California; (11) Esmeralda formation, Nevada; (12) Yellowstone Park; (13) Florissant, Colorado.

floras, but in order not to complicate the narrative, I propose to limit myself to those later ones enumerated in the preceding paragraph.

There is nothing more dramatic in earth history than the effects of the elevation of a mountain range across the path of the prevailing moisture-bearing winds, which converts the leeward country—often spoken of as lying in a rain shadow—into a semiarid or quite arid region. Nowhere were the effects more tremendous than in South America where the Andes—unusually high mountains—bisect the equatorial and south temperate zones in the paths of two of the most constant wind systems of the globe—the southern trades and the "roaring forties." Although the western American mountains are lower, and do not interrupt as constant wind systems, the effect of their elevation was almost equally remarkable, for the Rockies, Sierras and Coast ranges reared their present bulk in late geological times in a forested country, and their present comparative nakedness was quite absent at their birth.

The single restricted species of Glyptostrobus of China is almost as much like our American bald cypress as the redwood is like the big tree. Near relatives among plants like members of a human family naturally dwell together. If we encounter a man in Boston who has a brother in Vienna we know of a certainty that one of the brothers has moved either from Boston to Vienna or from Vienna to Boston. Similarly among plants when we find a sassafras or a tulip tree in America and another in China, we know that their ancestors have spread from the one region to the other and that something has changed the intervening country so that it is no longer habitable for them. This is really reducing the illustration to the lowest common denominator of simplicity, and the ways of nature or the story of earth history are never simple. Often along such past paths of dispersal are localities in every way suitable for an animal or plant and yet it is no longer found there, and this has a double meaning. It means that once they flourished there and then changed conditions rendered the region untenable, and since it has reverted to something like its original condition the particular animal or plant can not gain access because of natural barriers that have developed.

A thousand such illustrations could be given. Perhaps the most striking is furnished by Europe. Nearly all the American or Asiatic plants which are no longer natives of Europe, but whose ancestors were there in the late Tertiary, will flourish when reintroduced by man.

The Chinese tree of heaven (Ailanthus) is found fossil in the late Miocene lake beds at Florissant, Colorado, and at other places and times in North America, but has not been a native for hundreds of thousands of years, and yet it has become effectively naturalized in the last few centuries since it was reintroduced by man.

One of the most extensive as well as interesting of these western Miocene floras (Loc. 1) is that found in and around the city of Spokane in eastern Washington. Here in late Miocene times surface flows of lavas from the great Columbia area dammed the streams, and in the lakes which resulted the vegetation of the surrounding lands accumulated and much of it was beautifully preserved in the muddy sediments that were deposited. More than half of the sixty-six genera which have been identified from these deposits are unrepresented in the existing flora of Washington, and twenty-five of them are no longer present in western North America. This contrast between the past and the present is largely due to the fact that in Miocene time the Spokane region was one of abundant and well-distributed rainfall, and the Miocene forests were mixed hardwoods much like those of the present time in eastern North America. The post Miocene elevation of mountains has converted the region into one of lessened rainfall, temperature extremes and a relatively short growing season, so that those Miocene plants which could not maintain a foothold on the western facing rainy slopes of the rising mountains, or amid the somewhat changed conditions in the stream valleys, became extinct. These comprise an impressive list and include the hickory, chestnut, beech, elm, hornbeam, fig, tulip tree, magnolia, sweet gum, hydrangea, linden, sassafras and persimmon. All these are still present in the forests of eastern North America and in the corresponding forests of eastern Asia.

The largest western Miocene flora known is that found at Florissant, Colorado (Loc. 13). There more than two hundred and fifty different kinds of plants have been discovered, along with thousands of insects, beautifully preserved in the sediments of a small lake, which in upper Miocene time occupied a basin or park in the rising Rocky Mountains west of the present city of Colorado Springs. The sediments are largely made up of fine volcanic ash, which accounts for the excellence of preservation of the plant remains, since the finer the sediments the more faithfully are the details of the fossils preserved. A considerable number of the Florissant plants are identical with those found around Spokane, and many more are closely related. No horse-chestnut, tulip tree or sassafras have been discovered at Florissant, but a number of plants otherwise unknown in western Miocene floras or in the present floras of western America have been found. These include the Chinese tree of heaven (Ailanthus); the custard apple (Anona); the mostly tropical genera Bauhinia and Sterculia; the mulberry, which still has two species in eastern America and several in eastern Asia, as well as in other parts of the world; the syringa (Philadelphus), extensively cultivated and surviving in eastern America, eastern Asia and central Europe; and the devil wood, surviving in the Atlantic Coastal Plain from North Carolina to Louisiana and often called the American olive, and with several species in eastern Asia.

At all the localities where Miocene fossil plants have been found—the more important of which are shown on the accompanying map—the story is much the same. Nearly all have revealed the same species of magnolias, sycamores, poplars, oaks, willows, etc., showing essentially similar conditions of life, and containing in greater or less representation forms common to the existing floras of eastern America and eastern Asia, forms still present in more or less restricted areas in western America, and forms no longer represented in American temperate floras.

A few of these western Miocene plants deserve more than a mere mention. Thus the maiden hair tree or ginkgo, which is present in considerable abundance in the rocks of Oregon and Washington, has a single existing species now rather well known because of its rather wide cultivation as an ornamental tree in temperate climes. Darwin called it a living fossil, and it seems to have escaped total extinction by centuries of human care in the temple gardens of eastern Asia. Its ancestral history goes back to remote geological times long antecedent to the first flowering plants. During the age of reptiles (Mesozoic) it was present over practically all of North America and all of the other continents except Africa and South America, and in the earlier part of the age of mammals (Tertiary) it still flourished in the Arctic, Europe, Asia and western North America. It seems as if the climatic changes which accompanied the glaciations of Pleistocene time were responsible for its extinction throughout its former wide range, and only in Asia, where the topography and geography afforded an accessible asylum, did it live on for our ultimate enjoyment.

The bald cypress of the southeastern United States and Mexico, associated with De Soto's search for the fountain of youth and Cortez' overthrow of the Aztec empire, is another tree which once flourished over all the northern continents and was found in the West as late as the Miocene in Oregon and Washington. For some unknown reason it failed to survive in eastern Asia, where, however, it is represented by a relative—the unique and still more restricted glyptostrobus. Some of the Mexican cypresses are said to be longer lived than the giant sequoias of the Sierra Nevada, and one at Popatela near Mexico City, picturesquely called *arbol de la Noche Triste,* is associated with that grievous night in Cortez history when all seemed to be lost.

The sequoia, most famed of trees, has been the theme of song and story, and has been the mecca for an age of tourists for so long, that it would be trite to dwell on their present isolation or their past or present grandeur. Not every one knows of their ancient lineage and wide distribution, or that you may observe *their petrified stumps at Florissant, Colo., or in the wonderful petrified forests of fossil ridge in Yellowstone Park, or that as late as Miocene time their remains* are to be found in Oregon, Washington, California, Idaho, Yellowstone Park and Colorado, as well as in Europe. In Europe it was the Pleistocene glaciation which was their undoing on that continent and in western America their partial extinction resulted from the aridity due to mountain uplift over so much of their former area of distribution.

The incense cedar, a large and stately tree found singly or in small groves along the Cascades, Sierra Nevadas and Coast ranges from Oregon to Lower California, has existing relatives in eastern Asia and in such remote regions as Chile, New Caledonia and New Zealand. It has come down to us from remote geological times and although its ancestry is shrouded in darkness it has been found in Miocene rocks in Washington, Oregon, Idaho and Colorado, showing that it was a fully accredited member of the mesophytic forests which in the late Tertiary extended over such a large part of the western United States.

It would interest only botanists to enumerate all of the plants of the western Miocene with their ancestral history and the vicissitudes of their descendants, so that I will give only a few incidents regarding the more widely known forms. The figs belong to a great genus with hundreds of living and mostly tropical species. They are found on all the continents both at the present time and during their geological history. To-day the native American species are few in number and do not range north of southern Florida, although the cultivated fig grows well in California and as far north as Maryland along the Atlantic coast. Leaves of figs are found in the Miocene in Washington, California, Yellowstone Park and Colorado, and they are abundant in the clays of the Latah formation around Spokane.

Water chestnuts (Trapa), whose curious horned fruits are such striking objects, are no longer natives of North America, although frequently introduced. They flourished on this continent from the Eocene to the Pliocene, and their characteristic fruits are found fossil in the Miocene of Idaho and Nevada.

Among the plants which are confined to a single region in modern floras is the sweet fern (Comptonia). Its single existing species may be found as a hillside shrub from Nova Scotia to North Carolina. Its ancestral history goes back to the dawn of the flowering plants, and it was formerly present in a variety of species on all of the northern continents. In Miocene times it was still present in Europe, in Japan and in Washington and Colorado. We can only surmise why it died out over all of this enormous area.

Among the better known temperate trees which are members of the existing forests in Europe, Asia and eastern North America, but are no longer found in western North America, are the beech, elm, chestnut and linden. All have a long geological history which I have described in another place.[1] All are abundantly represented in the western Miocene—the beech in Washington, California, Idaho, Yellowstone Park and Colorado; the elm in Washington, Oregon, California, Yellowstone Park and Colorado; the chestnut in Washington, Oregon and California, and the linden in Washington and Colorado.

Two trees which survive in limited areas along streams in California, where each is represented by a single species, are the sycamore and the horse chestnut. Both are also found more abundantly to-day in eastern America, Europe and Asia. Both have a long geological history, the sycamore being especially varied, abundant and wide ranging in the earliest known forests of flowering plants. In our western Miocene the horse chestnut was found in Washington and Oregon, and the sycamore was apparently abundant and characteristic throughout the whole western country for it has been recorded in beds of that age in Washington, Oregon, California, Idaho, Nevada, Yellowstone Park and Oklahoma.

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[1] **Tree Ancestors, published in 1923 by the Williams & Wilkins Co.**

Familiar trees or shrubs which were abundant in our western states during the Miocene, but are now extinct in that region and survive only in eastern America and eastern Asia, are the hickory, magnolia, sweet gum, hydrangea and persimmon; and to these may be added the tulip tree and sassafras, which as yet are certainly known from but a single locality in Washington.

The hickory, unlike its near relation—the walnut, which still survives in California—was found on all the northern continents from the early days of the flowering plants almost to the dawn of written history. In modern floras it has long been supposed to be confined to eastern America where it has numerous fine and useful species. Recently it has been found to be present in the forests of central China. In the western Miocene it has been detected in Washington, Oregon and Colorado.

The magnolia, favorite ornamental tree with hundreds of horticultural varieties, is native in southeastern North America and eastern Asia, in fact the whole magnolia family has a disconnected distribution in existing floras. It too goes back almost to the dawn of the flowering plants and was widely distributed in former times. In the western Miocene it has been found in Washington, Oregon, California, Yellowstone Park and Colorado.

The sweet gum, whose beautiful star-like leaves contribute such striking tints to the vernal and autumnal woods of eastern North America and eastern Asia, was found on all the continents during the later Tertiary. In Miocene America it was present in Washington, Oregon, California and Colorado, and at the first of these localities its characteristic fruits, or gumballs, are associated with the leaves.

Hydrangea, which is more familiar as a cultivated shrub than as a wild plant, belongs to a genus with about 35 existing species of shrubs or small trees now found in southeastern North America, South America and eastern Asia. One of its peculiarities, on which its favor as a cultivated plant depends, is the tendency it shows for some or all of the small flowers of its flower clusters (corymbs) to become sterile and consist merely of 3, 4 or 5 enlarged and showy sepals. The selection of this feature by gardeners has resulted in the completely sterile large single or double clusters of flowers of the favorite cultivated forms.

The geological history of Hydrangea is very imperfectly known, but it is of much interest to find its large sterile 4 or 5 sepaled flowers preserved as fossils in the Miocene of Washington, Oregon and Colorado—showing thus early the natural tendency toward the production of sterile flowers, and furnishing another link between the existing floras of eastern America and eastern Asia.

Outside the range of the eastern persimmon, associated with the possum in southeastern North America, I doubt if Americans have any concept of persimmons other than that of the large fruited cultivated form introduced from eastern Asia. The persimmon belongs to a large and mostly tropical group which furnishes the ebony wood of commerce, and it has been a native of North America since Upper Cretaceous time. As late in the Tertiary as the Miocene it has been found in the west in Washington, Oregon, California, Yellowstone Park, Colorado and Oklahoma, and the fossil leaves are frequently associated with the characteristic large cruciform calices which subtend the soft and perishable fruits.

Among the western Miocene trees the tulip tree and sassafras are in a class by themselves since they are certainly known at only a single locality in Washington in beds of this age. Both have a history going back to the Mid-Cretaceous; both were long thought to survive as single species in southeastern North America; and both have been discovered in recent years in the forests of central China. Both were abundant and varied in the west during Upper Cretaceous, and both are wanting or sparingly represented in that region in Tertiary deposits. Both have now been found in the Miocene around Spokane, Washington, and will undoubtedly be discovered in other Miocene deposits in the West, since they were evidently members of the Tertiary holarctic flora, having long been known from Europe and Asia in beds of that age.

We have now glimpsed the changes which time has wrought in the distribution of our forests, and have sensed the hoary antiquity of most of our familiar tree genera. It has been shown that western America, with its mostly unique existing flora, was once a link in the chain of mesophytic forests which girdled the earth before the days of the Pleistocene glaciers, the cave man, and the existing mountain chains. We have seen also that the Tertiary plants moved as freely as the Tertiary animals to and fro across the land bridge connecting Siberia and Alaska when this was emerged and the climate permitted.

It is hoped that this brief sketch will interest a wider circle in the marvellous history of the earth and its inhabitants, and will reawaken in modern man that veneration which early man rendered to the trees as the abode of spirits—which is indeed true—for they still harbor the spirits of the past, and that inspiration which attaches to the living survivors of an ancient and noble race.

CLIMATIC FEATURES OF YELLOWSTONE NATIONAL PARK

By EDGAR H. FLETCHER

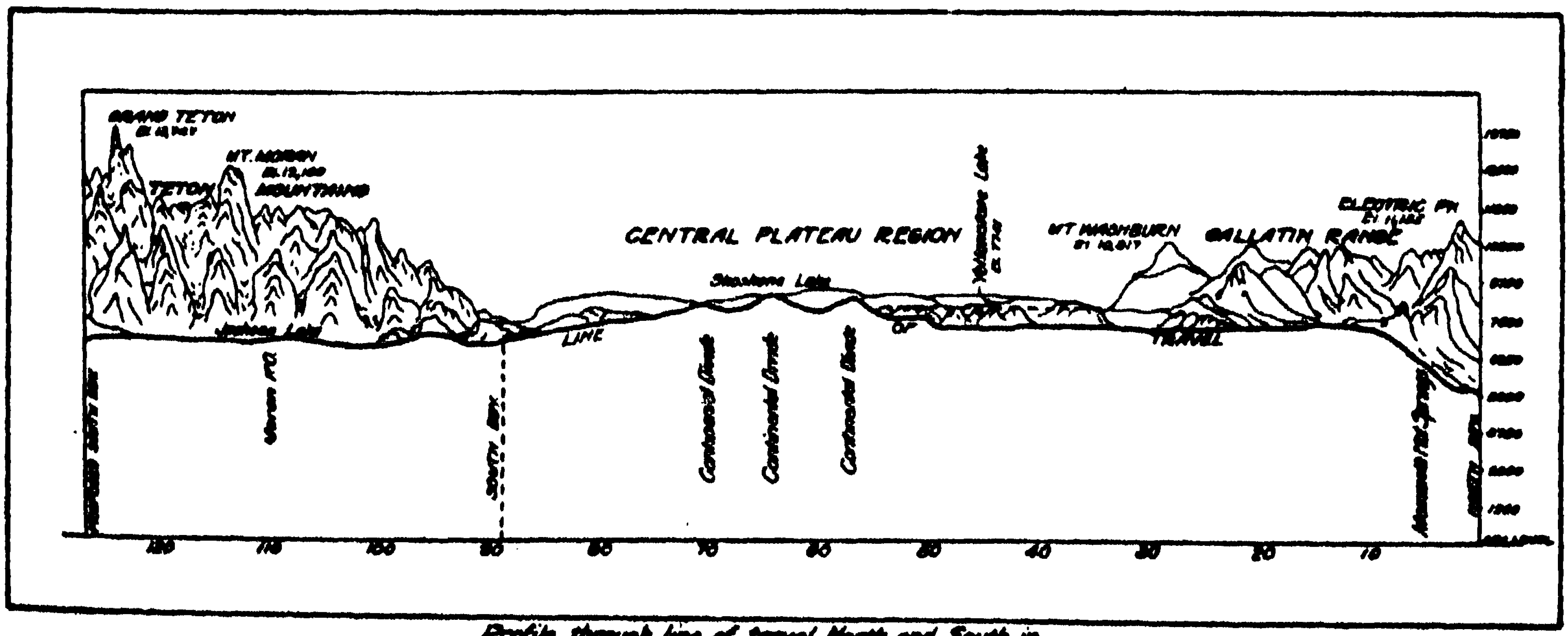
WEATHER BUREAU OFFICE, YELLOWSTONE PARK, WYO.

THE nature of the many inquiries on the part of the ever-increasing throngs of tourists that annually visit Yellowstone National Park would indicate that the weather and climate of this unique region is not well understood. The object of this article is to set forth some of the salient climatic and allied physical features peculiar to this vast wonderland that has been set apart "for the benefit and enjoyment of the people."

The Weather Bureau Observatory, erected in 1903, is situated on a built-up section of extinct hot springs formation on a northeast mountain slope at Mammoth Hot Springs within the park, five miles south of the northern entrance at Gardiner, Mont. At this place are located the local and field headquarters of the National Park Service; also the Yellowstone Park, Wyo., post office. The elevation here is 6,241 feet above sea-level; latitude 44° 58′ N., longitude 110° 42′ W. The general character of the vicinity is mountainous, with elevations reaching to 8,000 and 9,000 feet within a comparatively short distance.

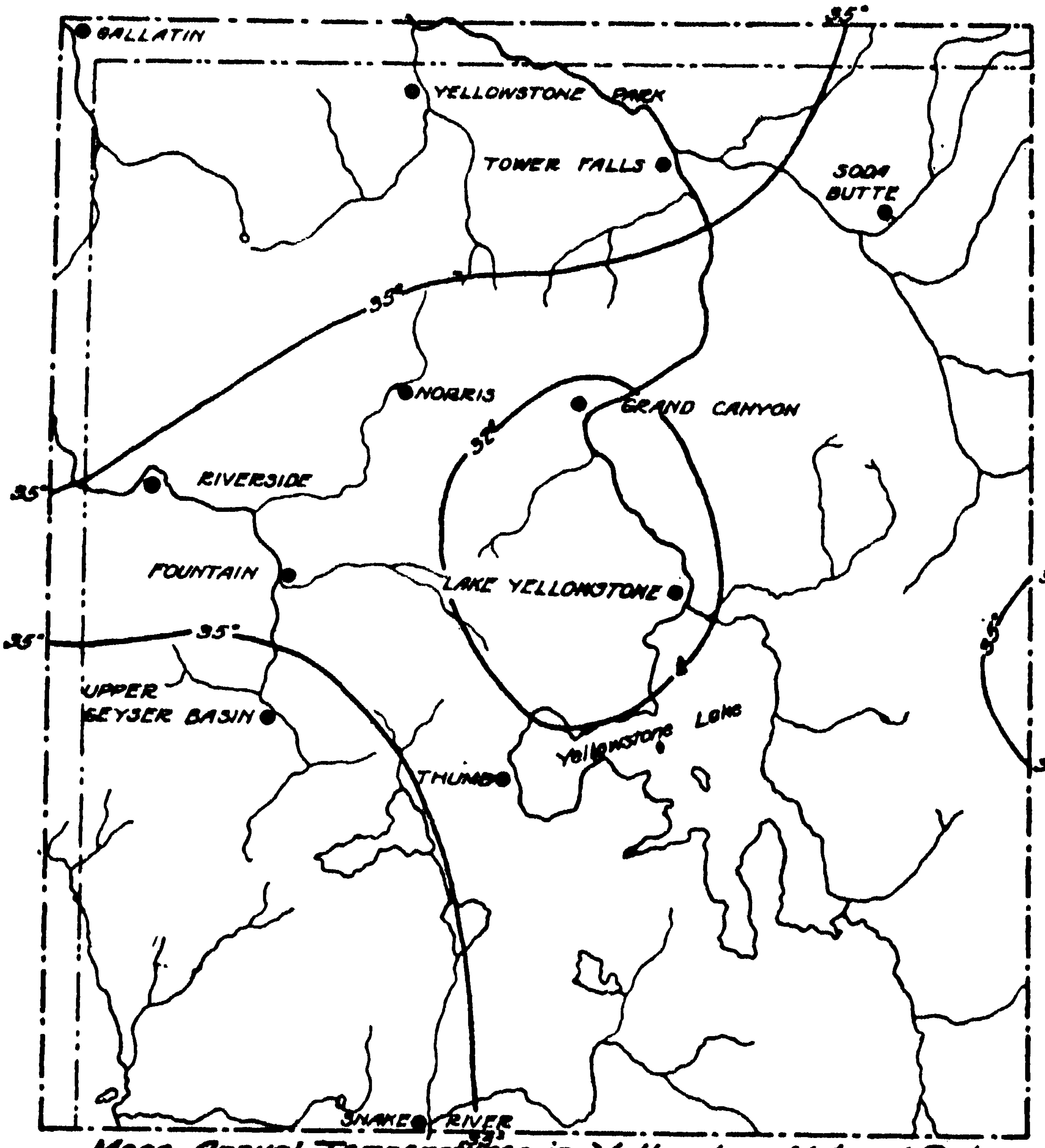
From the northern entrance near the mouth of the Gardiner River canyon, past Mammoth Hot Springs through Golden Gate canyon to the main plateau-level of the park, the elevation rises from 5,300 feet to 7,500 feet in a distance of less than ten miles. This may be seen from Figure 1, which is a north-south profile of the whole park region, including the Teton Mountains and Jackson Hole section.

Yellowstone National Park at present comprises an area of 3,348 square miles or about the combined size of Delaware and Rhode Island, and contains more spectacular hot-water phenomena, in the form of active geysers and hot springs, than all the rest of the world combined, besides being the world's greatest wild animal preserve. Its great central plateau has an average elevation of approximately 8,000 feet, surrounded by mountains whose peaks rise to from 10,000 to



Profile through line of travel North and South in Yellowstone National Park and region South of Park including Teton Mountains and Jackson Lake.

FIG. 1



.Mean Annual Temperatures in Yellowstone National Park

FIG. 2

11,000 feet, embracing a section of the main ranges of the Rocky Mountains. The whole region is built up of material once ejected from far beneath the surface by volcanic activity.

Within the central valleys are located several lakes, the largest of which is Lake Yellowstone, with an area of 139 square miles, the second largest body of water at its elevation in the world. The Yellowstone River is the outlet of this lake, and its placid waters a few miles north plunge over gigantic waterfalls into a canyon of indescribable grandeur and magnitude.

However, this is characteristic of all streams flowing out of this elevated region several thousand feet higher than the surrounding country. A series of cascades or cataracts is formed where the water flows over the edges of the igneous rocks. Some of the larger rivers, as the Yellowstone and Gardiner, have cut deep chasms or canyons far back into the lava beds within the park, thus producing high waterfalls and steep cascades almost within the heart of this region.

The Continental Divide, traversing the southwestern section, sheds the waters of the park to both the Atlantic and Pacific Ocean. Three large rivers, the Snake flowing westward to the Columbia, and the Madison and the Yellowstone flowing northward to the Missouri, have their head waters in this region, which has aptly been termed the "top of the world."

Authentic weather records date back to 1887, the early record of temperature and precipitation having been made under the direction of the army surgeon stationed at what was then known as Fort Yellowstone. Subsequent to 1903, a fully equipped meteorological station has been in operation, and continuous autographic records are made of temperature, rainfall, wind direction, wind movement, sunshine and barometric pressure. The anemometer, wind vane and electrical sunshine recorder are located on the roof of the two-story Weather Bureau building, which is surrounded by an open lawn of one acre. The thermometer shelter, tipping-bucket rain-gage and Marvin shielded rain-and-snow-gage are located over sod ground on rear of the reservation.

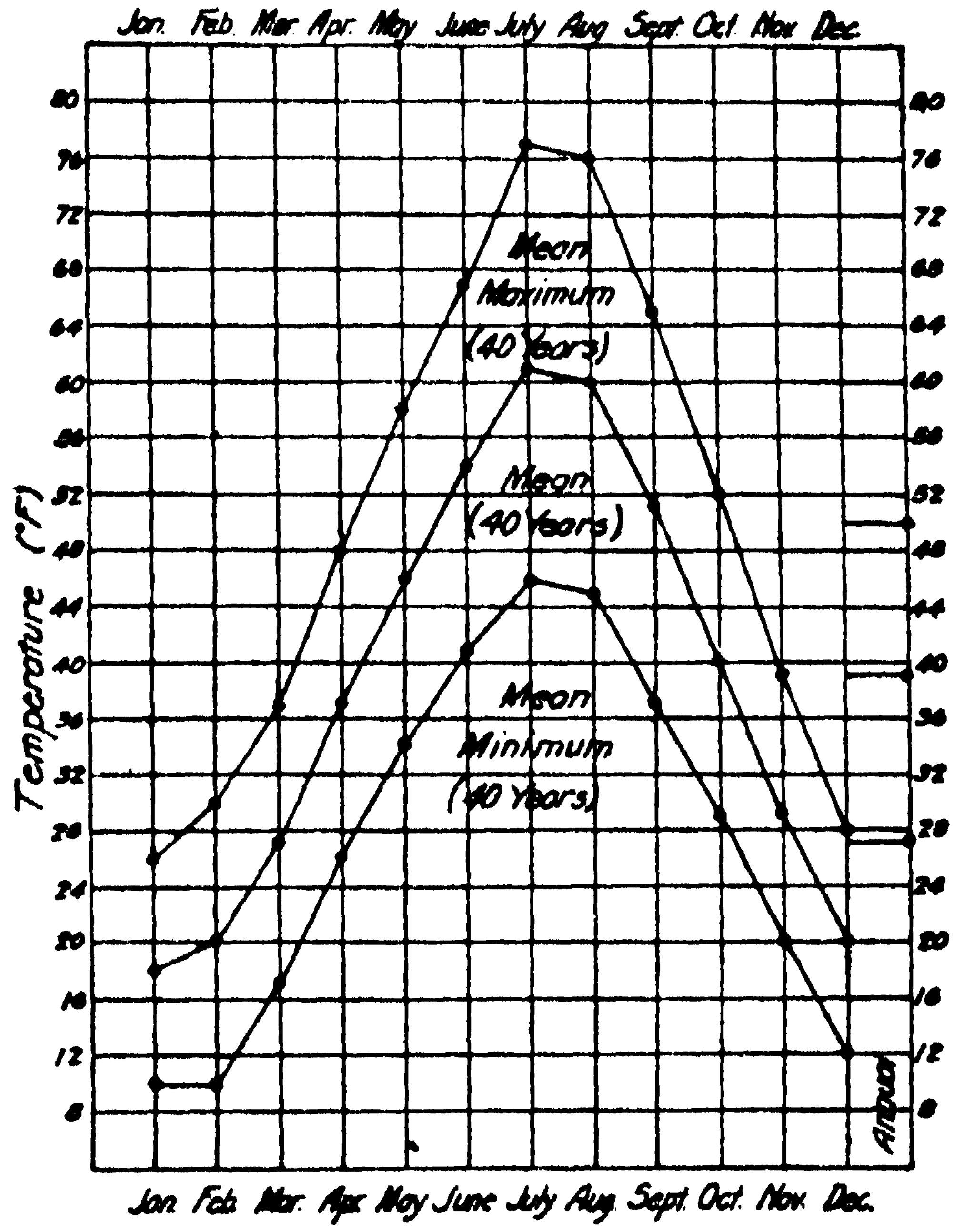
In cooperation with the National Park Service, records of temperature and precipitation have been made at twelve ranger stations at different points in the park.

The chief characteristics of the climate are the short, cool summers, the long, rigorous winters with a tendency to linger late in the spring, and the usually pleasant, open falls. The severity of the winters is not due so much to prolonged periods of extremely low temperatures, but rather to the persistence of comparatively low temperatures and much cloudy, unsettled weather with frequent light snows.

The occasional severe cold waves that occur do not continue for more than two or three days without some moderation in temperature. An exception to this rule was in the unprecedented cold wave of December, 1924, when the minimum temperature at the Weather Bureau station did not rise above 26° below zero for five consecutive days, and above 12° below zero for ten days.

Frost or freezing temperature occurs frequently at the higher levels, even in the summer months. A lack of knowledge of this fact is sometimes surprising, if not a little unpleasant, to the unprepared tourist coming from the hot weather prevailing at lower altitudes.

Except for slightly greater extremes, the temperature conditions over the main park plateau for the midsummer season compare closely with those of the midwinter months at Yuma, Ariz., and approximately with the early May temperatures at lower-altitude stations in the same general latitude.

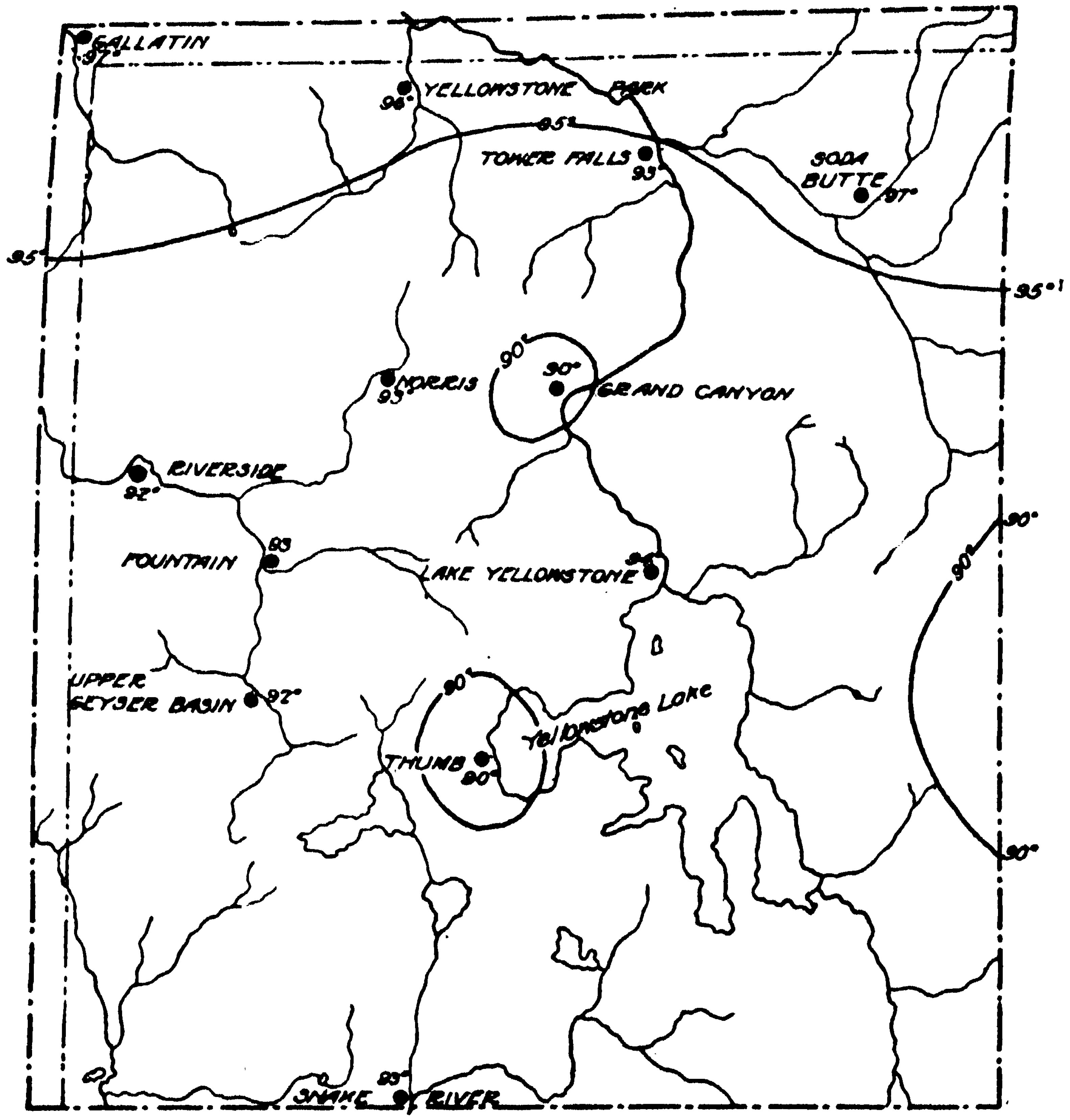


The march of monthly averages of temperature at Mammoth Hot Springs, Yellowstone Park, Wyo.

FIG. 3

The highest temperature ever recorded in the park was 97°. The record for the past 25 years shows that the temperature at the Weather Bureau station reaches 90° only once in about each ten years, but less frequently at places of higher altitudes.

The lowest temperature ever recorded was 59° below zero at Riverside ranger station near the western entrance, December 19, 1924. The 40-year absolute minimum temperature at the Weather Bureau station is 41° below zero, which occurred January 14, 1888. On an average, the minimum reaches 30° below zero only once in about each decade at the latter station, while occurrences of



Highest Temperatures Ever Observed in Yellowstone National Park

FIG. 4

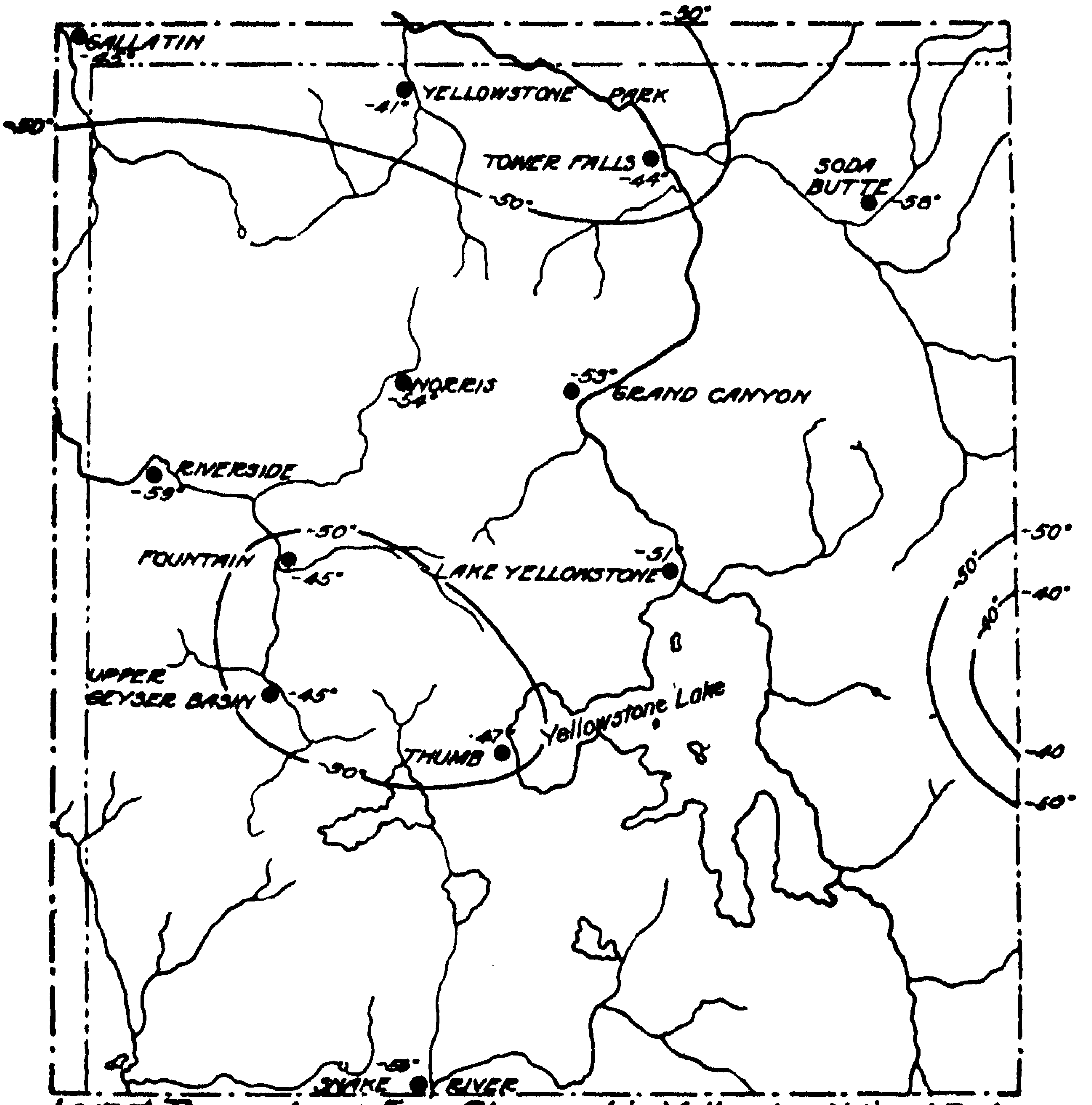
from 15° below to 20° below zero are to be expected almost every winter, and the average number of days annually with temperature of zero or below is 24.

But it must be remembered that much of the main region of the park lies above the 7,500-foot level, where a marked increase in the degree of severity of the winter climate prevails, as compared with the record at Mammoth Hot Springs. However, it may be stated that the effect of subzero weather seems to be somewhat ameliorated in this dry atmosphere.

The daily range in temperature in summer is quite marked, the temperature often ranging from 35° or 40° during the night to 75° or 80° in the afternoon. The summer and early fall seasons are especially delightful and invigorating, having an ample supply of sunshine under favorable temperature conditions. There being less scattering and absorption of the solar rays at this altitude by reason of the purity and dryness of the air, the sunshine is very intense and exhilarating. This accounts for the remarkable growth of native grasses and wild flowers during the extremely short growing season.

No agricultural pursuits are carried on within the park except that necessary to provide hay for the winter sustenance of the large buffalo herd, and to a limited extent that of the elk and other animals when natural forage is inadequate or buried beneath unusually deep or crusted snow.

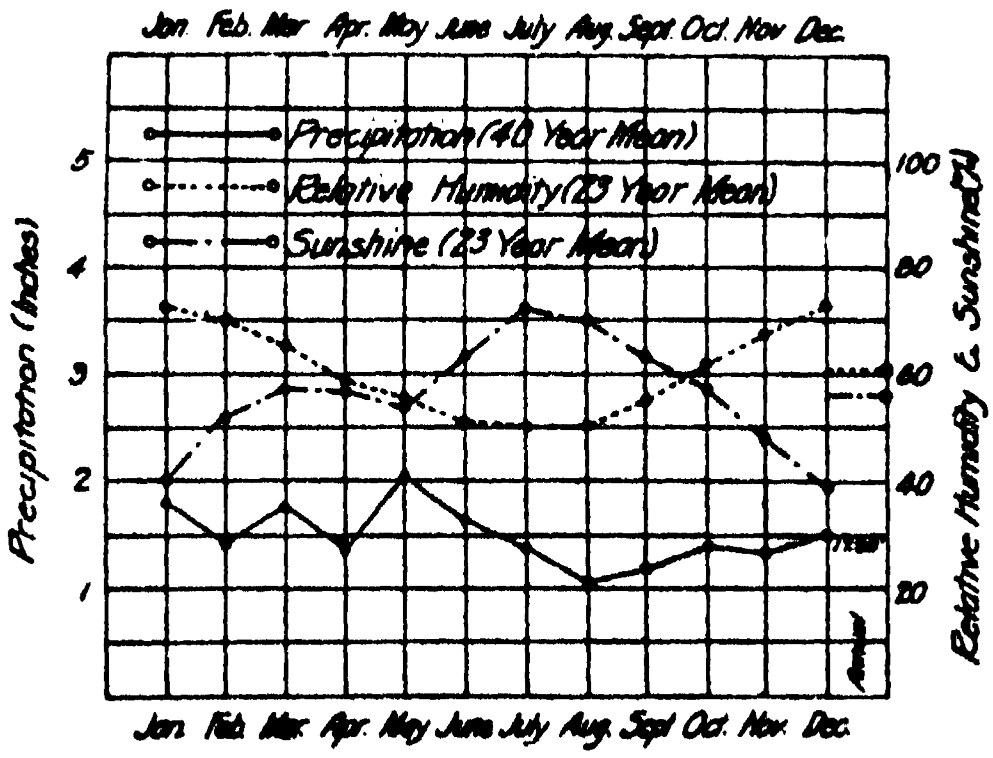
A wide variety of animal and plant life peculiar to the different temperature



Lowest Temperatures Ever Observed in Yellowstone National Park

FIG. 5

zones formed by the variation in altitude is found within the park, representing in latitude the region from the temperate to the frigid floral and faunal realms; but in the park the distribution depends upon altitude instead of latitude. This range of animal and plant forms may be illustrated by the bird-life. Such extreme forms as grebes, pelicans and thrushes show the wide range in classification; while the presence of humming-birds, the lazuli bunting, rosy finches and the Barrow golden-eye duck indicate the vast geographical range represented.



Monthly and annual averages of precipitation, relative humidity and sunshine at Mammoth Hot Springs, Yellowstone Park, Wyo.

FIG. 6

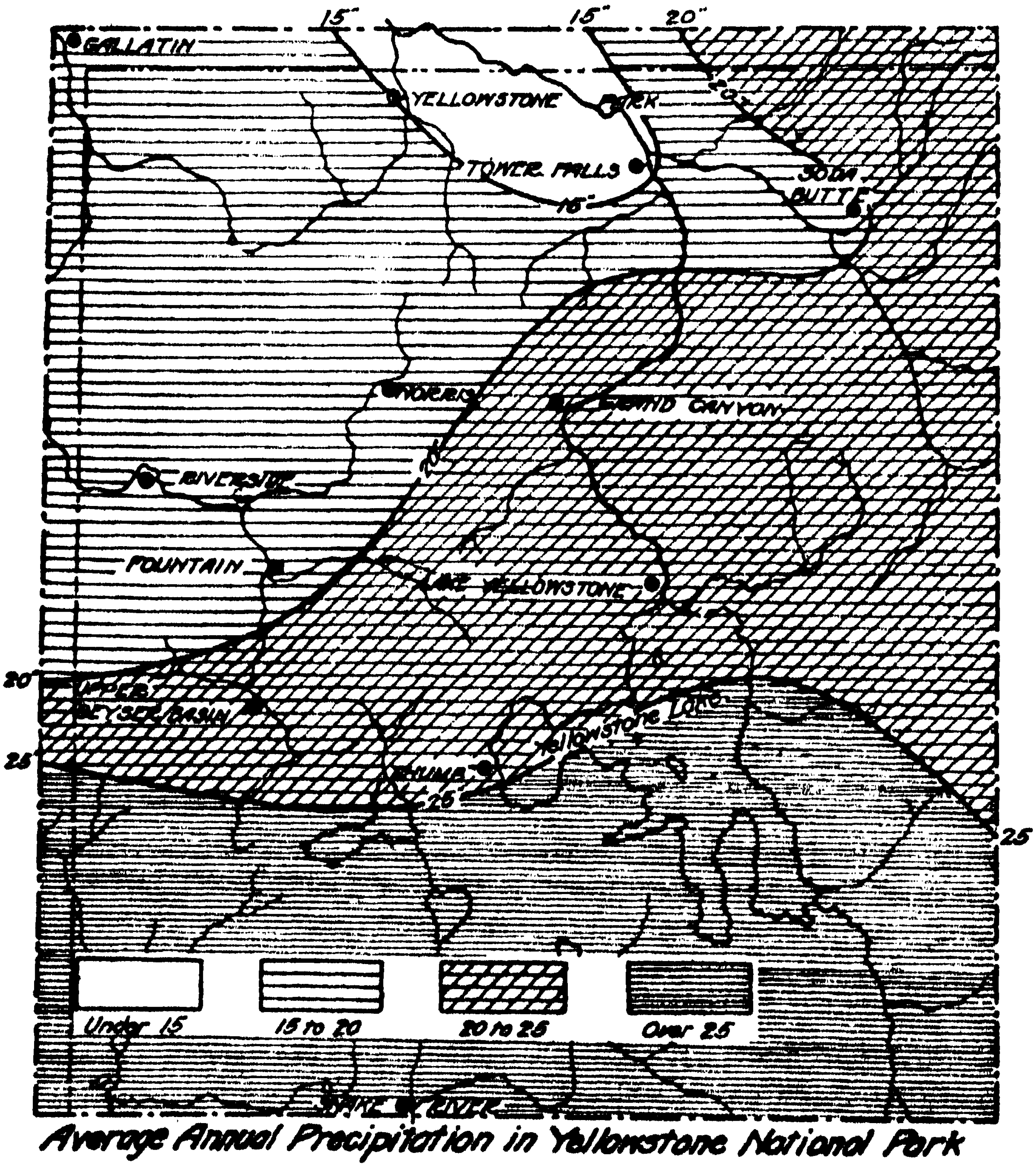
The normal annual precipitation increases from slightly less than 15 inches near the northern boundary to about 31 inches at Snake River on the southern border. The region is semiarid; and while precipitation is well distributed throughout the year, the winter and spring months receive slightly heavier amounts. Cloudy days with continuous rain are of rare occurrence at any season, but summer thunderstorms occur frequently, though usually mild in character and often accompanied by light hail.

The total annual snowfall at the Weather Bureau station is about 100 inches for the average season. Wide variations from this normal occur, however, ranging during the past 40 years from a maximum of 210 inches in 1890 to a minimum of 20 inches in 1915. On account of the low absolute moisture content of the air the average daily snowfall, except for an occasional storm at infrequent intervals, is extremely light, but it is of frequent and almost daily occurrence during much of the cold season.

The greatness of the total annual depth is chiefly accounted for by reason of the fact that very little melting occurs until spring. There is nevertheless considerable settling of the snow caused by days of comparatively mild temperatures, by an occasional, but not well marked, "chinook" condition, or by evaporation into the thin air prevailing at this altitude.

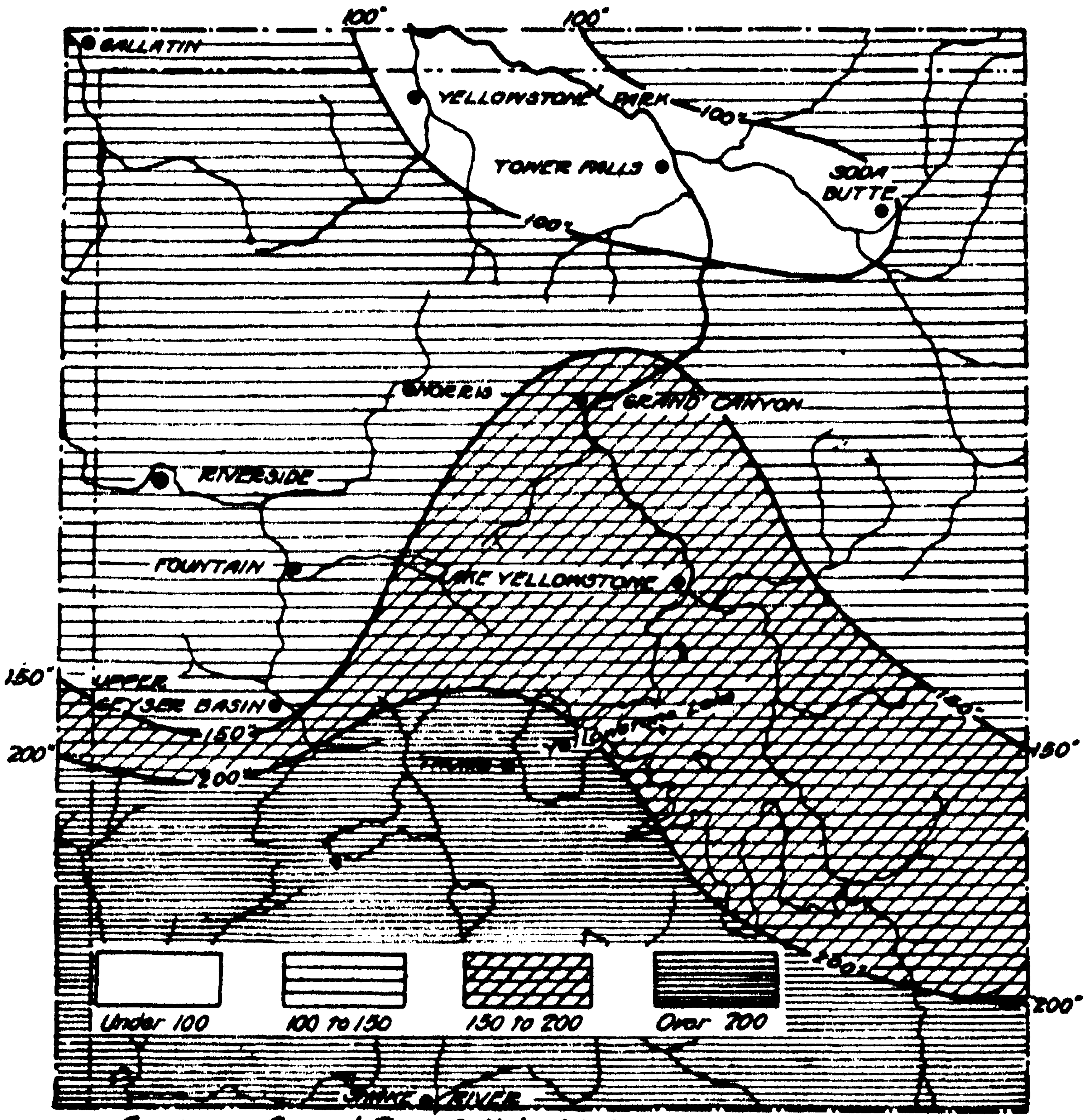
Snow in material depths does not normally accumulate at Mammoth Hot Springs until midwinter or past, and the highway from there to the northern entrance at Gardiner, Mont., is open for travel during the entire year. The average depth of snow on the ground at the end of February for a period of 23 years at the Weather Bureau station is 12.6 inches, while the greatest depth ever recorded is 35.6 inches in March, 1917.

In general the region of greatest snowfall is in the southern third of the park, where the average annual accumulation



Average Annual Precipitation in Yellowstone National Park

FIG. 7



Average Annual Snowfall in Yellowstone National Park

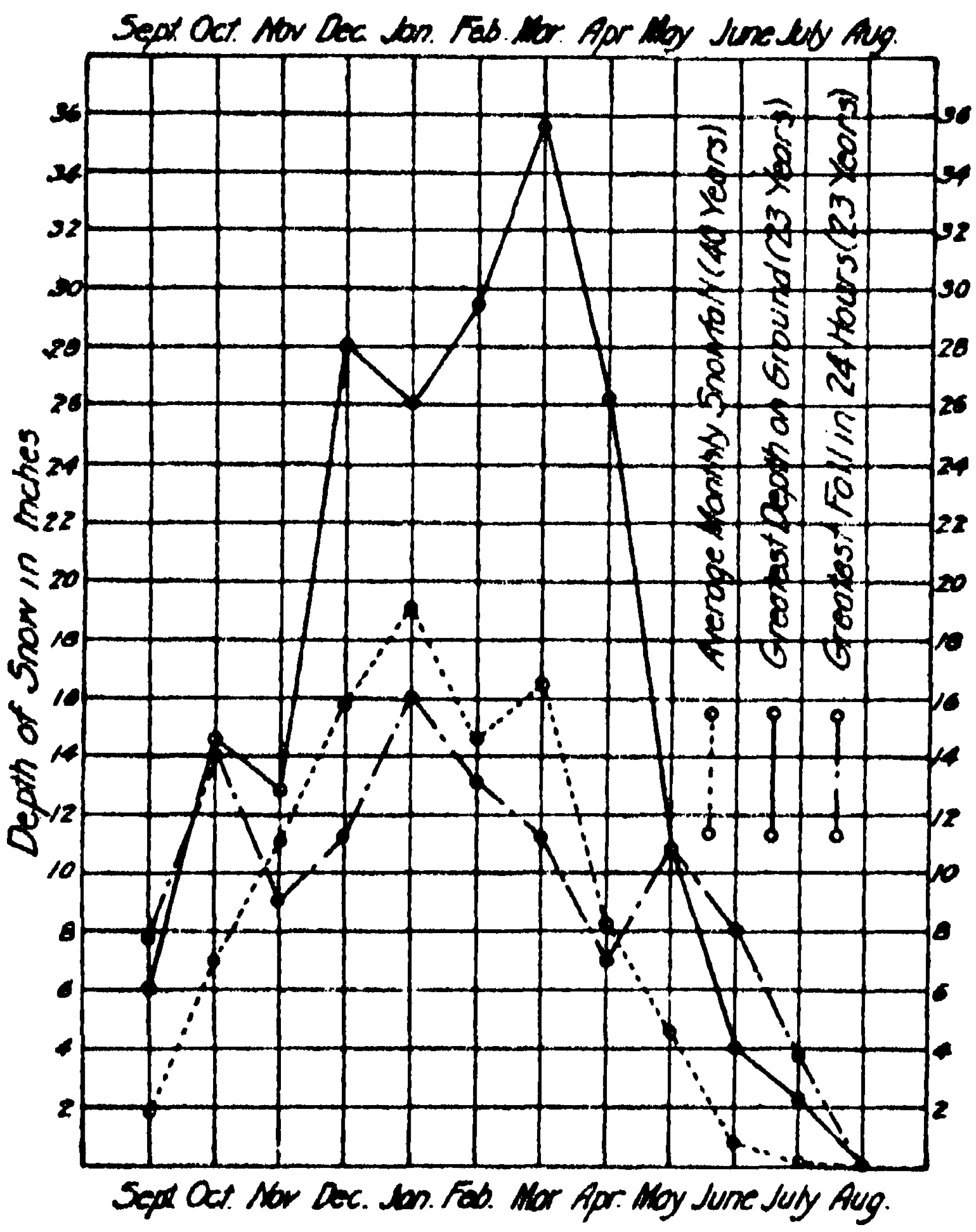
FIG. 8

is slightly more than 200 inches, and depths of upward of 100 inches on the ground are measured in the early spring. In years of abnormal snowfall, depths in excess of 15 feet accumulated on portions of the higher divides. This method of nature in storing moisture high up on the watersheds to be melted in the late spring or early summer, is of great economic value to the park as well as to regions at lower levels that depend upon its waters.

A season of unusually light snowfall has quite an adverse effect upon the park, as the proper display of many of the natural wonders crowded into this region depends upon soil moisture and stream-flow. The geysers and hot springs are more active with a plentiful supply of water. Snow in quantities that insure late melting not only contributes to the growth of an adequate supply of natural forage for the large herds of wild animals, but it materially minimizes the park's greatest menace—the fire hazard in summer.

Contrary to a popular belief, the weather at this place in winter, with its disagreeable features of cold, snow, wind and storm, is not without its economic importance; on the contrary, the country thrives because of it. Even the "ill wind" serves a useful purpose in drifting and piling the snow into deep depressions and canyons, and thus retarding its melting until late in the season. These large bodies of compact snow in sheltered places act as natural reservoirs to conserve the water supply, and to diminish destructive floods, which are sure to occur with the rapid melting of blanket snow.

While the wind movement is fairly active, velocities beyond forty miles per



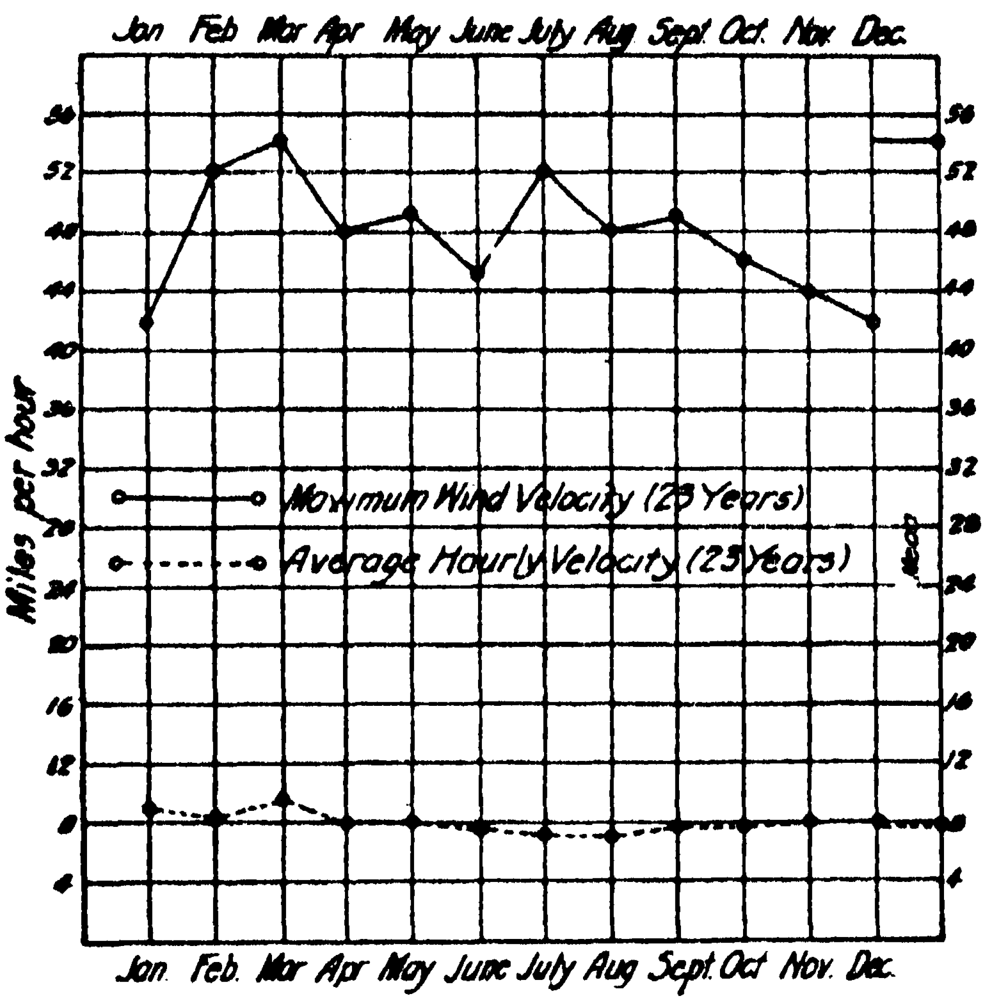
Seasonal Snowfall at Mammoth Hot Springs Yellowstone Park, Wyo
FIG. 9

hour do not often occur, except over the more elevated and open stretches. Situated to the southward of the main Alberta and North Pacific storm tracks, and at an elevation to be least affected by the deflecting influences of the surrounding topography, the prevailing winds are from the south and southwest for every month of the year. Northerly or westerly winds occur only for brief periods at rather infrequent intervals, and usually are accompaniments of cold waves in winter. No damaging storms have been recorded.

Fogs rarely occur, except in the vicinity of the larger lakes and in the geyser basins during the colder season of the year.

The hot springs and geysers do not affect the weather at any appreciable distance from their location. However, local condensation in fog-like form is quite marked in the main thermal regions in winter.

In a few remarkable instances the general severity of winter conditions fails to have its usual effect upon the fauna.



Maximum and average hourly wind velocity of Mammoth Hot Springs, Yellowstone Park, Wyo.

FIG. 10

This is due to the offsetting influence of thermal springs and warm, open streams. Thus it happens that one may have the weird experience of flushing Wilson snipe amid the snow and in the extreme cold of January, for the snipe remain all winter along the steaming overflow streams that carry off the water from Mammoth Hot Springs. Several other species of birds, which are ordinarily only summer residents in similar latitudes, remain along the open streams all winter.

Figures 3, 6, 9 and 10 show graphically the monthly values of temperature, precipitation, humidity, sunshine and wind as recorded at the Weather Bureau station, Mammoth Hot Springs, while Figures 2, 4, 5, 7 and 8 show annual averages and extremes for the entire park, as determined from the records of the 13 stations where weather observations have been made.

Owing to sharp differences in elevation within short limits, the climate varies considerably with location. Therefore, it should be remembered that wide deviations from the charted values may exist in the more elevated regions where no records have been kept.

RESEARCH WORK IN AGRICULTURE[1]

By President R. W. THATCHER

MASSACHUSETTS AGRICULTURAL COLLEGE

THERE have been three major influences operating to determine the character of the research in agriculture conducted by the Federal Department of Agriculture and the state experiment stations, three specific influences aside from the historical development of these institutions. Perhaps before I mention these three particular agencies I ought to say that historically the state experiment stations and, almost to an equal degree, the United States Department of Agriculture were originally intended to be referee or umpire institutions, to insure that purchasers of commodities to be used in agriculture were protected against fraud.

First of all, there is *the influence of legislation or legal enactment*. The original Hatch Act of 1887 provided for the establishment of state agricultural experiment stations, as follows:

> That it shall be the object and duty of said experiment stations to conduct original researches or verify experiments on the physiology of plants and animals; the disease to which they are severally subject, with the remedies for the same; the chemical composition of useful plants at their different stages of growth; the comparative advantages of rotative cropping as pursued under a varying series of crops; the capacity of new plants or trees for acclimation; the analysis of soils and water; the chemical composition of manures, natural or artificial, with experiments designed to test their comparative effects on crops of different kinds; the adaptation and value of grasses and forage plants; the composition and digestibility of the different kinds of food for domestic animals; the scientific and economic questions involved in the production of butter and cheese; and such other researches or experiments bearing directly on the agricultural industry of the United States as may in each case be deemed advisable, having due regard to the varying conditions and needs of the respective States or Territories.

Obviously the intention of the original Act was to provide for the study of problems in connection with the production of food and other types of material on American farms and the American farming industry was regarded as a production industry.

The second great federal enabling act, namely the Adams Act of 1906, provided for more adequate support for these institutions but did not modify in any way their purpose. The rulings of the Office of Experiment Stations with reference to expenditure of funds made available under the Adams Act were that they should be applied rather narrowly to fundamental researches rather than to more casual investigational work. The Adams Act had the effect of giving a higher and more definite conception to the term "research" than had grown up under the original Hatch Act.

Two years ago the third great federal enactment for the support of agriculture, namely the Purnell Act, was passed by Congress. This act did contribute a new aspect to the field of agricultural research, namely, that while it specified in particular that the funds made available under it might be used in extending and developing lines of research originated under the Hatch Act, the new funds might be used also for the study of problems arising in the distribution, marketing and consumption of agricultural products and of problems of rural sociology and economics. Hence, from the legal standpoint there is recognized the right of these institutions to undertake research in any aspects of the various fields of country life; that is, in the production of products, marketing, consumption in the home, in the social life of rural homes, and in the home-making problems in individual homes in rural communities. Legally, there has been set a certain wide boundary in the fields of investigation in which these institutions may engage.

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[1] Prepared when the author was director of the New York State Agricultural Experiment Station, Geneva, N. Y.

The second large influence in determining the type of research work which has been undertaken at these institutions has been *the personnel of the research staffs and their preliminary training.* In the early days of these research agencies, both in the United States Department of Agriculture and in the state experiment stations, the scientific staffs were drawn almost exclusively from the faculties of universities. They were, therefore, men who had grown up in the educational and research atmosphere of the so-called basic sciences. The staff in the early days may have had a horticulturist and agriculturist on its roll of titles, but much more commonly the men were classified as botanists, chemists, physicists, astronomers and other fundamental scientific investigators. Also, men who were given the title of horticulturist or animal husbandman were by reason of their previous training university men, trained in fundamental science, and not trained particularly in the application of that science to the industry represented by their particular title. Thus, these research agencies have had impressed upon them from the beginning the conception of the type of problem and method of attack which comes from university training in science, a most fortunate experience, I think, because it is necessary to the proper application of research to agriculture and home making.

The third influence which has come into bearing more recently in the life of these institutions is what might be called *the response to pressure from farmers and home makers themselves for certain types of study,* that pressure coming now principally through what is called the extension service of these institutions. This whole system has grown at an enormous rate, carrying instruction off the campus to people in their homes. The extension service being the third and latest group is now the point of liaison between resident teaching and research and men and women who are actually practising the art of agriculture and home making on their own farms. Through the extension service there is a constant pressure for the solution of certain problems which arise in the home or on the farm and with which there is now a definite point of contact through that service.

The agricultural research institutions themselves are conscious of those three influences—first, the legal; second, the personnel or training of staff; and third, the extension influence in determining the type of problem and method of attack which it is important for these institutions to undertake. Of the three, the second is undoubtedly the most far-reaching in its influence, because of the fact that while these institutions are organizations and have their own methods of administration, after all they are groups of individuals of strong and outstanding characteristics in the field of science. At least, we hope they are. And it would be impossible, even if desirable, to suppress the influence of these strong individuals and of their previous training and experience in fields of science in its effect upon the programs of the institutions.

In the second place, it is well to recognize at the outset that these institutions supported with public funds are not organized to do for farms and home makers the things that can just as well be done by the farmers and home makers for themselves, and perhaps be done better by themselves and for themselves. In other words, we ought to recognize, and I think we do recognize, that these are not institutions of practice or of the art of agriculture or the art of home making. The members of the staff are not selected because of their skill in the handicraft of food production. Many of them are better prepared for the service they are to render if they do have the skill and experience required by living in the country and on the farm, but primarily they should be selected, in my judgment, by reason of their scientific training and experience in order that they may bring to the problems of research the method of research. The method of research is scientifically acquired and is not usually acquired merely by experience. There are a few geniuses in research who have not been trained in its method, but most researchers are researchers because they have had long, painful, careful training in the method of research study. Hence, members of research staffs are primarily chosen by reason of their having acquired this technique. It is that type of service which the institutions of agricultural research ought properly to render to the commonwealth, to the state and to the nation. It would be a prostitution of their best function to say that they are rendering any other type of service, as I see it. I am still a firm believer that we must choose our staff of research men in an agricultural experiment station on the basis of their knowledge, ability and skill in the field of some science.

Of course, there is growing up a group of problems in the application of science to the art of agriculture and in the art of home making in which the definite scientific principle is not always so clearly to be recognized. We do have certain men and women who may be on our staffs because of their ability to interpret in terms of actual operation the scientific principle on which that operation is safely based; but, generally speaking, the research field concerns itself with the principle rather than with its specific application.

Some of my illustrious predecessors have said that it is not the function of the experiment station to teach the farmer how to farm, but rather to teach him how to think. I do not agree with them. I assume that research men have to do a lot of thinking and to use the knowledge and skill that is acquired by mental activity in a solution of the problem. I do think that the idea which I have just expressed has some basic foundation of fact in it. It is not the object of scientific research to produce rules of thumb to guide farmers and makers of homes, but it is rather to establish the scientific principles and the sound scientific facts upon which a successful system of operation for an individual farm or home may be established. That theory has grown up through fifty years of experience.

The experiment stations and the United States Department of Agriculture are being called upon to extend their research into the fields of economics and sociology. Here great confusion has arisen, because obviously the methods of research study are different when one deals with the physical problems of the universe from those encountered when one deals with the effects of personality and of social groups and social organizations upon existing situations. So it is still an open question whether the technique to be employed in these research agencies which have developed on the basis of the physical and biological sciences can be successfully carried over into the study of economic and social problems. At least at the outset there is great difficulty in employing the experimental method in the study of economic and social problems, yet we are being charged with the duty of investigating economic and social problems at these institutions in so far as they affect the agriculture and rural life of the country. Hence, the time has come when it should be realized that while there has grown up a very definite technique and a very definite field in the application of research to agriculture, the development is not yet complete because there are new aspects to the whole series of problems with which we are now confronted.

As bearing upon the question of state responsibility for research in these newer fields, I think we can safely say that we ought to capitalize the confidence which the people of the nation have in their unbiased research agencies for agriculture by extending the fields of the activities of these institutions into newer lines of economic and social study of rural problems; that we ought to guard with the utmost care the basis upon which that confidence has grown, namely, the giving of the results of research in such sound, unbiased, unpolitical form that they can be accepted with confidence as the basis for sound rural life and rural procedure. I think that this responsibility is recognized by administrators in the United States Department of Agriculture and in the experiment stations and that an effort is being made to carry over into these new studies the same attitude of mind and, so far as may be possible, the same technique of experimental investigation that has been so successful in the last half century in the field of agricultural production. But there is to be recognized, to be sure, a new field of technique, which must have time to work itself out and which is being carefully considered by those engaged upon it.

In conclusion, may I say just a word or two with relation to the possible coordination of research in the state agricultural experiment stations with other research agencies within the states and the nation. I think there has been less confusion in both the national and state affairs in the fields of research in agriculture than in other fields by reason of the fact that since the days following the Civil War a definite institution for agricultural research has been recognized in each one of the states. To be sure, other state agencies do undertake in some cases types of research which have an application to agriculture. In some states the state departments of agriculture have attempted to perform certain research functions; but, in general, by acceptance of the dictum of the commissioners of agriculture, it has been agreed that these state departments are executive, administrative or regulatory in function and that research belongs not to them but to the agricultural experiment station. In some states certain work in the forestry commissions, however, has a close relation to agriculture, particularly when it attempts to determine what use shall be made of land. In some states, the conservation commission has some relation to the agricultural policy, particularly when it concerns itself with utilization of land or other agricultural potentialities. But in general there has been a pretty clear line of demarcation, so that it may be said that the field and function of these research agencies in agriculture in the several states are quite clearly defined.

TROPICAL LIFE AS A FACTOR IN HUMAN EVOLUTION

By Professor **RALPH E. DANFORTH**
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TROPICAL and subtropical conditions have played a larger rôle in the early career of humanity than the masses today imagine and are pretty sure to play a great part in the future evolution of man.

A stupid notion that clings with surprising tenacity, in spite of much that has been written by travelers to the contrary, is the idea that tropical conditions lead to indolence and degeneration in man. Many of the very people who turn with awe to the early and venerable civilizations on the Nile, the Euphrates and Tigris may be inconsistent enough to say in the next breath that man degenerates in the warm countries.

At the present time thousands of families in Hawaii, in Australia, India and many other parts of the tropical world are living not only healthy but active, alert, productive lives, as efficient, if not more efficient, than they would live in cold regions. The benign living conditions of the warm regions, however, permit those who are hereditarily indolent, ignorant or even vicious to live and to multiply who would be killed by the inclemencies and extreme, sudden changes of so-called temperate regions.

There are some fever-stricken stretches of scorching sand, dotted with palms, like the prevalent popular conception of tropics, but the prevailing types of trees in the tropical world are not palms but broad-leaved trees, of infinite variety, in general aspect somewhat like those of the north, while the scenery may be as diverse, rugged, picturesque and inspiring as any this world affords. The temperature varies, with altitude, from perpetual summer, through perpetual spring to perpetual winter in the tropics. Also there are regions perpetually dry and regions perpetually wet, regions dry half the year and wet the other half, regions with any conceivable combination of dryness or wetness one might seek. In western tropical America one can get plenty of change of scene and of climate in a short trip by auto, but few changes come to him in any single spot. Far different is the picture in the average man's mind when he slurringly speaks of the tropics.

It was under genial conditions that the earliest great civilizations developed through thousands of years of change in man's mental makeup and culture, affecting his physical habits at the same time.

Many millenniums before civilization man hunted and fished and gathered wild fruits, roots and nuts in regions adapted to his unclothed, sensitive body, so ill-adapted to extremes of temperature. Man's physical requirements are undoubtedly for a very mild and genial climate, and wherever, as in the temperate and arctic zones, we find him adjusted to very different conditions, it is by artifice, gradually acquired, that he has contrived to make it possible for his warmth-loving body to live in health, although the time elapsed has been far from sufficient to permit the body to physically adapt itself to the rigorous climates without artifice.

The artificial heat and the elaborate protection which we require are greatly favored by the generous stores of mineral fuel. As population increases, and coal and oil supplies diminish, and the near water-powers are fully developed, there will still be an increasing demand for fuel. This fuel will have to be grown. Vegetable fuel and food are stored-up solar energy, and can, therefore, be grown fastest and most cheaply where there is the most sunshine, namely in the tropics. Here timbers of all degrees of softness and hardness grow with much greater speed than corresponding timber would in the north.

Increasing supplies of food and fuel and lumber will find their way from the tropics northward and southward into the cooler regions in future. Increasing numbers of folk with good heredity will probably colonize the pleasanter regions of the tropics, at moderate altitudes. There they will not need fuel except for cooking or manufacturing. There they will not need to store forage for their livestock, but they will have fuel and food and forage right at hand, and may produce it rapidly and for an indefinite length of time.

Roses and jasmine may be grown in abundance, all around one's home, the most fragrant varieties and the most beautiful being selected of course. Lilies, heliotrope, gardenia—and many other flowers of beauty and fragrance may be massed in the gardens. For its marvelous perfume an ylang-ylang tree (*Canangium odoratum*) should be planted, while against some support the false ylang-ylang, a semi-climbing shrub with fragrant yellow flowers, may be grown. The allamanda, with its huge cups of brilliant gold, will brighten its environment throughout the year.

Birds and butterflies will cheer the heart with their sprightly beauty each day. Verdure and life and growth go on about one all the time. The shortening days do not shorten enough to bring the touch of melancholy.

The open-air life is lived all the time, for even when busied in a building the large and numerous windows and doors are always open. Streets and roads may be dusty, but one may locate somewhat above and away from these. The purest fresh air may be had always by those who plan aright and seek it.

Ultra-violet rays, so healing and so vigor-conserving, abound in the generous sunshine of the tropic regions, and need not be lost in window glass. Undoubtedly much of the unsanitary neglect and ignorance of many natives is in part compensated for by the health-giving sunshine and open air. There is no need to shut one's self in for the long winter months, nor to clothe one's self heavily.

Fresh fruit, just picked from the trees, is always in season—if not one variety, then another, always one's choice of several, throughout the year; and green vegetables from the gardens.

Dairy cows and poultry may have the vitamin-producing rays of the sunlight, and hence keep their milk and their eggs in the most serviceable state through the entire year. Experiment has shown that in northern winters eggs and milk may be deficient in vitamin D. Even the milk of nursing mothers has been shown to lack this essential when the mothers spend most of their time indoors.

Human evolution in the present and the future may be affected by life in the tropics, therefore, by increased esthetic pleasure from sights and sounds abounding in life, beauty and sparkle; by increased health and comfort; by time, money and energy saved from fighting winter, and from costly preparations for winter, and so set free for constructive work aimed toward real and lasting progress; by an environment which can be made into a more ideal one than would be physically possible to north or south of the tropics.

SOCIOLOGY AS SCIENCE

By Professor FRANKLIN H. GIDDINGS
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SOCIOLOGY is a contemplation of our most awesome folkway, namely, our habit of trying out *en masse,* solemnly and ceremonially all possible ways of going wrong before going right. The contemplation is an esoteric amusement and potentially a science.

The definition is derived, by a transposition of clauses, from Herbert Spencer, who was only talking, and not trying to define anything.

Science has had a hard time since it arrived at *cogito ergo sum,* and is not yet done with trouble. It not only contends with hostile ignorance, it also fends against mischief set going by certain of its own devotees, who play "off side" for their own purposes. The sciences of mankind in particular are discredited by obfuscative originality. Sociology as a would-be science of society has been held back a full generation by sociologists who have not heeded Comte's warning against metaphysics and the revolutionary impulse. Many of their philosophical disquisitions and uplift stories have been valuable, but they have not been science.

In so far as *a* science is a distinct part of science viewed as an indivisible whole it has become such by concentrating inquiry and perfecting a technical method. Because of the distinctiveness of facts upon which it can wisely direct inquiry, and of a method which it can effectively use, sociology can be more than an assembling and ordering of checked observations—an achievement not to be despised, but it can not become like chemistry or like astronomy a prediction of certainties. It can become a forecast and a measurement of probabilities (including contingencies of kind and correlations of size) in the field of those human relations which constitute *normal society, i.e.,* society made up of *the most frequently recurring* combinations of societal components and attributes.

Our daily behavior is adjusted more to probability than to certainty. In the morning we note the weather prediction "probably showers," or "probably fair." We go to the railroad station to take a train that probably will arrive as scheduled, and convey us to our destination in time for appointments made as a "safe bet." The insurance companies sell us policies based on a calculated "expectation" of this or that. The things that we do with one another, against one another and for one another, and the relationships that we enter into, from marriage to trusteeship or politics, are contingencies which can be predicted for populations and social classes within ascertainable limits of error. How organized society of known composition and pattern will carry on in given circumstances is never a matter knowable to a certainty, nor wholly unknowable. It is knowable as a probability, expressed as a percentage of certainty, symbolized by unity. The sociologist can determine limits of variability and trends of change in society with closer approximation to truth than hit-or-miss popular thinking can, or than legislators do.

Frequency distributions of a large number of interesting and important facts about human beings have been worked out, and others will be. Of those which particularly concern the student of society, distributions of the phenomena of population have so far received chief attention, and, starting from them, progress has been made in determining a considerable number of important probabilities. Among these latter are the probability, positive or negative, that inter-continental, intra-continental and intra-regional migrations will reach a maximum extent and then diminish; the probability that population growth beyond a certain maximum speed will slow down; the probability that the concentration of population in urban areas will not continue at its present rate; the probability that the ethnic heterogeneity of modern populations consequent upon inter-continental migrations will not greatly increase from now on.

Distributions of population according to mobility, density and composition affect human attitudes, behavior, relationships, undertakings and achievements. Therefore probabilities (positive and negative) which vitally interest us are contingent upon these distributions, and now and then are closely correlated with them. Among such are the following: the probability that wars will diminish in frequency and destructiveness; the probability that violence, truculence, intolerance, bullying and lesser meddling will diminish; the probability that knowledge will become effectively ascendent over credulity and zealotry; the probability that the organization of society and the administration of institutions will become less rigid, less clumsy, and more adaptable to variant conditions; the probability that control by society over its members will become less coercive and more discriminating; the probability that human communities will escape the fate of such communistic insects as ants and bees, among whom "workers" (a majority of all individuls) are standardized defectives; the probability that human individuals will become more highly individualized and individually more responsible—in a word, more truly personal.

Not many of these probabilities will be determined by statistical assaults along extended fronts.[1] Most of them await an accumulation of painstaking minor studies into which big researches must be resolved. Recent examples of this procedure which come to mind are Woofter's study of the correlations of negro migration with economic, political and educational changes; and Stuart A. Rice's studies of significant correlations of political with more basic societal phenomena in the Non-Partisan League area of the Northwest.[2]

By technical method (an application of the logic and calculus of probability) and by concentration of inquiry upon the variabilities and the trends, the normal constitution and the normal functioning of human society, sociology is marked off in a broad way but not in detachment from other studies of human relations, namely, history, economics, public law and politics as the theory of the state.

History has a technique of criticism, and economics a technique of evaluation. Public law and the science of the state have a technique which consists in an application of the tradition and principles of judicial interpretation.

All these studies give chief attention to human doings and relationships that have been radically and extensively conditioned by obedience-demanding governments, which have commanded, prohibited, ordained, and instituted. For example, the commercial activities and relations which interest the economist have been radically and prevailingly conditioned by the institution of property and the law of contract. History no longer ignores the pre-political chapters of human experience, but it continues to occupy itself chiefly, and perhaps always will, with events in which governments have played a major part. Public law and the theory of the state are primarily concerned with sovereignty, and its expression in the constitution of the state, in government, and in law.

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[1] A challenging possibility, however, is contributed in "The Biology of Population Growth" Raymond Pearl, Baltimore, 1925; and "The Natural Increase of Mankind," J. Shirley Sweeney, Baltimore, 1926.

[2] "Negro Migration," Thomas Jackson Woofter, New York, 1920; "Farmers and Workers in American Politics," Stuart A. Rice, New York, 1924.

In western civilization, so called, the human activities and relationships that have been radically conditioned by governmental constraint are of bewildering multiplicity. Nevertheless, even in the Occident, not to mention other parts of the world, they are not yet the most frequently recurring ones, and by that token not the predominating constituents of normal society. Of course they have never been the primary or basic ones. Folkways, born of impulse, habit and preference are more nearly universal than state ways, and mores are more generally observed than laws. Sociology, respecting the preemption by history, economics, public law and politics of the domain of governmentally conditioned affairs, appropriates to itself a more pristine realm.

Normal society as here defined is *natural society,* in the sense that it is a growth. It is not created out of hand by fiat. It is engendered and it engenders. Bentham's well-known discrimination of political from natural society is essentially true, but his conception of natural society will bear expanding. It is true that talk is the primal social intercourse and the last to be inhibited, nevertheless, natural society is more than a lot of talkers talking. It comprises all associations (companionships, coteries, partnerships, companies) whether transient or enduring, casual or devised, *which have not yet been radically or extensively conditioned by an obedience-demanding government.* It originates in simple phenomena of human kinship, casual acquaintance, and talk. It carries on through mutual aid. It proceeds by folkways of usage and convention. Without much of taking thought it becomes organized into a mesh of relationships which are by-products of birth, propinquity, interest and activity.

Deriving from the series biology, psychology and anthropology, scientific sociology is a natural (or naturalistic) science of natural society, viewed as a normal, human-conduct part of the normal order of nature, and as explainable, therefore, only in terms of what we somewhat broadly, but with fairly definite meaning, call natural causation.

Constraining powers, governmental and other, germinate within natural society and, growing rankly, react upon it. By incorporating the nation, which is a natural society (or, as sometimes happens, by incorporating a fragment of a nation, or a combination of nations) the constraining powers, asserting themselves as sovereign, create the political state, a legal entity. The state by incorporating local communities, which are natural societies, creates minor legal entities, namely, municipalities.

But to the extent that the state refrains from constraining and institutionalizing or does not completely succeed in its attempt it fails to recondition, radically, our common activities and relationships, and natural society persists. Thenceforward we are at one and the same time members of natural society and citizens (or subjects) of the state. The associations to which we belong and within which we work and find satisfactions are in law subject to the state, but are not actually subjugated or transformed by it. The family, for example, has been institutionalized in legal theory and to a great extent in fact, but that it remains primarily a natural family, such as one finds among animals and in primitive human groups, there is abundant evidence, in romantic marriages, common law marriages, desertions and separations, and survivals of polyandry and polygamy. New rituals and sects, and new non-conformist churches arise in every land and age to contend with established religious orders. Private schools and endowed colleges and universities compete with public schools and state universities. New political parties spring up, and now and then one survives. Agitations and movements, including those which sway governments and shape legislation, are phenomena of natural society, as witness the Renaissance, the Reformation, Puritanism, the anti-slavery struggle, and, more recently, communism and pacifism.

So, it appears, not only is natural society more or less conditioned by the state, but also the state is conditioned by natural society, which now and then nullifies law and defies government. There is no "unconditioned power to compel obedience" in the world of political actualities. The notion was one of the choice properties of political metaphysics. Natural society may even break up the state by revolution and then permit a new sovereign to recreate it.

Professor Burgess found in the state a sphere or realm of government, and a sphere or realm of liberty, and the state itself he resolved into a state that is organized in the constitution and a less obvious state (a constitution-revising power) behind the constitution. He came near to identifying the state behind the constitution with natural society. If identification be made complete the state, strictly defined, becomes primarily the realm of government, and natural society remains the primary or original realm of liberty. Civil liberty, so called, is a compromise. It is natural liberty conditioned by government. Natural liberty is habit-made, not fiat-made, so also is respectful obedience of law, and the two habits are not incompatible. The citizen who is solicitous about the future of either liberty or respect for law and desirous of knowing the "expectation of life" of either of them must study sociology. He will find enlightenment nowhere else.

In summary: Sociology is the science of natural society, viewed as a normal growth and scheme of folkways and relationships not yet radically conditioned by an obedience-demanding government. The data of sociology are checked observations. Its descriptions are frequency distributions of components, constituents and patterns. It seeks types, averages, deviations, coefficients of variation and of contingency and trends. Its forecasts are probabilities.

INVENTION AS A LINK IN SCIENTIFIC AND ECONOMIC PROGRESS[1]

By Professor SIR JAMES B. HENDERSON, D.Sc.

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INVENTION and discovery are so closely allied that they are often confused. In our common speech the two terms are frequently used as synonymous, and if one seeks an exact line of demarcation between them one finds it difficult, if not impossible, to distinguish one from the other in any but the most general terms. Both involve an increase in knowledge which may be great or slight, and may have an immediate effect or may take a lifetime or more to consolidate. Both involve scientific imagination. Each may be only a happy idea, the inspiration of a moment or in some cases an accident, but the testing of the idea and its final enunciation as a physical truth or as a finished invention may occupy many years. Newton is reputed to have discovered the theory of gravitation on seeing an apple fall from a tree, but assuming that to have been the birth of the idea we know that the completion of his discovery and the proof of the universal law of gravitation took the best part of his lifetime and involved the invention of new branches of mathematics to complete the proofs. The record of Newton's work has been so ably revised during the past year by Sir Oliver Lodge, Professor Turner, Sir Frank Dyson and others, in connection with the Newton bi-centenary celebrations, that these matters must be fresh in the memory of all.

Were I asked to distinguish between discovery and invention I would say, in very general terms, that the dividing line is the same as between theory and practice, between the abstract and the concrete. Discovery is essentially an increase in man's knowledge of nature and its complexities, and is therefore intangible. It may be a discovery of a new principle, a new element, a new and hitherto unknown quality or characteristic of a known substance, and so on, but the discovery, *per se*, has no regard to any particular practical application of the new knowledge. Invention, on the other hand, has its sphere in the practical application of knowledge, and the knowledge used may be new or may be as old as the hills. It may be, and it is often the case, that invention involves other discoveries which may be complementary to the original discovery and form its completion, or may be entirely unrelated to it and form the nucleus of a new branch of study. It is possibly this fact, that the difficulties encountered in developing an invention often lead to new discoveries, which makes it so difficult to separate discovery from invention. I think, however, that this distinction in general terms is sound, that discovery is mental, while invention is material, and while it is true that in the large majority of cases an invention is in its origin a mental conception, it is a conception of something material and practical, while a discovery begins and ends in the realm of the mind.

Discovery and invention are important links in the chain of progress but neither marks the end of the chain. The discovery has to be proved or the invention has to be reduced to practice. This brings in a third link, finance. The Einstein theory, for instance, could never have been tested and established without the assistance of capital to finance the extensive eclipse observations which converted it from a pure mental conception to a working theory. The assistance of capital in the development of great inventions of recent years is a necessity too well known to need description.

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[1] Presidential address before the Section of Engineering of the British Association for the Advancement of Science meeting at Leeds from August 31 to September 6.

Here then we have a series of operations. First comes the fundamental discovery laying bare one more of nature's secrets; then invention turning the discovery to practical use; and lastly, the hand of finance to help dreams to come true. The first is a matter of genius or inspiration coupled necessarily with deep study. The second needs skill in the arts and crafts and generally a high degree of patience and courage to weather the disappointments and setbacks which we are too prone to call failures. The last, though it may be allied with technical knowledge, requires most of all the commercial instinct to sense to-day the needs of to-morrow, coupled with faith in the invention and the inventor and courage to see the task through to the end. We are often told that the financial world of to-day worships above all things a fat and speedy dividend, but when one thinks for a moment of the amount of capital that must have been spent, often fruitlessly, in financing the discoveries and inventions of the past and realizes at the same time the number of other channels open to finance in its own immediate sphere, offering possibly greater certainty and speedier returns, it is surprising, not that it is so difficult to obtain finance for a pure scientific invention, but rather that it is possible to find it at all. It says something for man's imagination that finance with its many other opportunities is willing, even to a limited extent, to place its resources at the disposal of scientific progress in the courageous belief that it is casting its bread on the waters of knowledge and that in good season it will return.

When one seeks to study the history of some of the great inventions, one begins to realize how exceedingly complex they are, despite their outward appearance of simplicity. As an example take wireless telegraphy and telephony. No single person deserves the credit for its discovery and invention. Maxwell, Hertz, Lodge, Crookes, Branly, Marconi, Jackson, Fleming, de Forest, Fessenden and many others have contributed their share to its development, but the basis of wireless communication did not necessarily begin with Maxwell. What was it caused him to conceive the idea of the electromagnetic theory of light? Most probably he was trying to explain, like many others, the experimental fact that the ratio between the electro-magnetic and electrostatic units was the velocity of light, and having conceived a possible explanation he proceeded to work it out and test it, and the electro-magnetic theory was the result. The original idea may have been a lightning flash of inspiration, but the complete mathematical theory was the work of years.

Hertz was the first to produce apparatus for transmitting and receiving wireless waves, and this apparatus was improved by Branly, Lodge and many others, but for further progress finance was needed. The first steps to make a wireless telegraphic installation were taken in Italy by Marconi and in Great Britain by the Admiralty experiments carried out by Admiral Sir Henry Jackson, who was then a captain. In this kind of competition money counts for much, and in the development of an invention having a commercial as well as a service aspect a commercial firm with good financial backing will always have a great advantage over a government department with a strictly limited budget allowance for research. It says much, therefore, for the scientific direction of the Admiralty of that time that the Admiralty are to-day numbered among the pioneers of this great invention.

I have taken wireless as a typical illustration. To the man in the street it represents simply an invention, a single invention and an apparently simple one represented by a small wooden box with a knob to turn. But to the scientific historian who tries to decipher all that the little box represents in human thought and effort, it presents an appearance of amazing complexity in which the discoveries and inventions of some of the finest brains of two centuries are inextricably blended. The proverbial tree of knowledge is a good simile. It grows incessantly but imperceptibly, sending forth new shoots which in turn become branches and subdivide in their turn. Growth is not confined to the shoots, however, and a continuous process of consolidation and expansion is taking place in the trunk and root and branches. The sprouting of a new shoot is a new discovery and the consolidation work behind it and upon which it is based is invention.

INVENTION AS A HISTORICAL SCIENCE

Invention being generally concerned with the application of physical forces in the service of man may at first sight appear to be a branch of physical science pure and simple. It is, however, actually concerned less with the scientific principles of physics than with the human element, with limitations which that element imposes, with peculiar conditions under which the forces of nature have to be applied and with the unknown elements in physical science. It belongs, therefore, if treated as a science, by itself, rather to that group of sciences which are concerned with humanity and nature at large, the so-called historical sciences. Economic science, a typical historical science, is studied by thousands as a science, yet it has no fundamental physical principles like the conservation of energy on which to build its superstructure, because its working material is the human element which has not so far been reduced to any fundamental basic principles worthy of the name of laws. It is in what Lord Kelvin would have called the natural history stage of its development, during which observations are made and correlated, to be followed by the natural philosophy stage when the fundamental principles are discovered which explain the observed facts and cast upon the scientist the mantle of the prophet.

A historical science which is studied at great length in the staff colleges of the armies and navies of the world is the science of war. It has no fundamental scientific physical principles as basis but is founded simply upon deductions made from a close study of warfare from all times. Wars are analyzed, tactics and strategy studied with the view to learning from the history of centuries of war useful lessons to guide the soldiers of today and to safeguard them against repetition of the mistakes which have caused the disasters of the past.

The science of invention is a curious blend of the exact sciences, like mathematics, physics and chemistry, with a historical science. It is in many respects similar to the science of war, the war being against the complexity of nature, man's ignorance of that complexity and the inefficiency and insufficiency of the human intellect itself. Whether nature be regarded as a cantankerous old dame ever ready to take advantage of a false step, neglecting no opportunity to obstruct, and resenting every attempt to reduce her movements to law and order, or whether she be regarded as a kindly old lady in the middle of a sun-lit lawn, calling softly "Come and find me" to a crowd of eager, blindfold children, the fact remains that she and man are age-old opponents in a contest from which there can be no discharge to the end of time. Yet if we compare this contest with the wars of man with his fellow man, what a difference we find. Napoleon said he learned the art of war from a study of the lives of the great captains, but in the greater war with nature if we consult the books that have been written round the lives of its great captains we find only human documents in which the searcher after knowledge to help him to carry the fight a little further, finds little help beyond an example of high courage. The technical difficulties are seldom recorded and the new searcher has generally to start afresh and reconnoitre his way across the old battle-ground of centuries. The fault sometimes lies with the chronicler but too often with the lack of records which the captain might have left but failed to leave. In fact here we have a startling lesson from the science of war, for is it not drummed into every budding soldier till it becomes second nature when he attains command, that one of his first duties in the field which must never be neglected is to maintain communication and pass on all information that may come his way, whether it be useful to him or not. The lesson has two sides. The soldier knows that he may become a casualty at any moment and the information which he gleans may be of vital importance to enable someone else to carry on in his stead, also that information which may appear unimportant to him may prove to be the key to the movements of the enemy elsewhere of which he is in entire ignorance.

Any invention starts with a scheme which, on paper, promises to be successful if the fundamental assumptions or information on which the scheme is based are correct. Just as a general draws up his scheme of attack based upon certain assumptions or information regarding the enemy's disposition, numbers and probable future movements, so the inventor lays his plans to curb and control nature by a scheme based upon assumptions as to her behavior. When the general finds that the enemy is stronger than he thought, or that he has shifted his ground and is turning his flank, or generally that the enemy is not playing the game which he had been expected to play and which had been provided for, he has to modify his scheme and proceed on new lines, so also the inventor has frequently to change his plans on discovering that Dame Nature is not quite so simple as he had believed and is seemingly getting the upper hand and laughing at his efforts to control her. So the fight goes on from day to day, from year to year, and there are very few great inventions which are brought to a successful issue without departing in some respect or another from the original scheme and without the expenditure of many years of effort and large sums of money. The records of the various attacks and their results in the series or chain of maneuvers which are finally crowned with success are rarely written, and in the much larger proportion of long engagements which are finally abandoned as failures no record of any kind is published and most valuable information is lost forever.

Contrast this with military or naval wars in which records of every little move are faithfully kept and are studied by the historian, who draws from them lessons for future generations of soldiers.

The history of the nineteenth century and the enormous economic and political progress made in it might be summed up in the word "Invention." As was pointed out so clearly in Sir John Snell's presidential address to Section G of the British Association at the Oxford meeting, economic progress can be best measured by the amount of horse-power used per head of the population, and since every successful new invention increases this amount both in the manufacture of the gear itself and by the power it may control, it is very evident that economic progress is closely allied with invention. The invention of the steam engine, the spinning jenny, the power loom, the steamship, the power printing press, the dynamo, the electric lamp, the steam turbine, the electric telegraph and wireless telegraphy, not forgetting the chemical industries, form the economic history of last century, yet no one, so far as I am aware, has studied the development of any of these inventions with the view of learning therefrom and recording lessons which can be passed on to posterity.

Of the hundreds of inventions which have been abandoned as failures, or of possibly revolutionary inventions left incomplete simply from lack of capital or lack of courage, no record is available to those who come after and who might carry them on to success. Has every inventor for all time to start from scratch? The same difficulties crop up time after time in the development of inventions, yet every new inventor has to tackle the difficulties *de novo,* and fortunes are wasted in the process. Development of an invention is always costly, even when guided by all the experience obtainable from allied inventions; how much more costly it is when not so guided the history of the failures would most surely show. In most inventions there comes a time when the inevitable question arises, "Shall we cut our loss or risk further expenditure?" If the decision is to cut the loss, the invention, which is possibly a sound one and of great value, is pronounced to be a failure and the result may be the loss of an industry to the country or a delay in its introduction for many years. Science will prevail in the long run, but the cost of the trials both in time and money could probably be greatly curtailed if records of similar ventures in the past were available. Inventors would gain much if they could be trained in, and benefit by, the experience of their predecessors in the same field, while masters of industry, with records of that experience before them, would be better able to appreciate the difficulties of the inventor and to cooperate fully with him.

No one would dream of putting a general in command of an army who had not previously studied the art of war either in staff college or in the field, nor would they put an engineer to construct a bridge unless he had some experience in bridge-building; yet in the development of an invention some seem to think that no previous experience is necessary and the work is frequently left to the inventor himself, who may have no knowledge of the practical or commercial side of development, or it may be given to someone who has no previous experience of similar development but who is supposed to be a good practical man, though devoid of scientific knowledge of the principles to be followed.

In the development of inventions no general rules can be laid down because inventions take so many different forms, and the expert in developing inventions, say, in the chemical industry, would not offer an opinion on the development of inventions in complicated mechanism. Why is it that chemical reactions which work well in the laboratory on the small scale in vessels of glass or platinum so frequently go wrong when tried on a larger scale in works in vessels of porcelain or the baser metals? The expert in developing inventions in the chemical industry has had much experience in overcoming these difficulties, but little of that valuable experience has been published.

In every industry one finds that the experience thus gained in developing the inventions of the industry is guarded as a most valuable secret. The result is that this knowledge is not recorded and often dies with the individuals who possess it. Future workers even in the same industry have to pass through the same or similar experience to regain the lost knowledge and the whole condition is economically unsound. The expense to the nation which it entails must be enormous. It retards progress, it adds greatly to the time and expense of developing other inventions, and it brings invention into disrepute because so many firms have lost money in trying to develop inventions which have had to be abandoned simply through inexperience.

The value of experience in any particular line of invention is that it puts the owner of the experience in the position, when called upon to express an opinion on a new invention, to form an estimate of the type of difficulties likely to be encountered and the time and expense likely to be required to surmount them. The novice always underestimates both the difficulties and the cost of development, and many failures are due solely to this underestimation, while the man who has once been bitten tends to overestimate them and to suspect difficulties where there are none, with the result that the development of the invention is unnecessarily delayed.

NURSING AN INVENTION

So far I have dealt with the sequence of operations of discovery, invention and the financial and technical assistance in development, but the process does not stop there. Once an invention has been developed and made a commercial article, it merely enters upon a new phase during which it requires the most careful attention. It requires nursing. It may be sold to users who are free to submit it to any use or misuse they like, and even when properly used trouble is sure to arise somewhere and it is usually difficult to say whether the fault arises from legitimate use or not. This is a most critical financial stage because the invention, if put on the market too soon or without full experience of every detail, may be killed by financial failure due to faults introduced often by an ill-considered change of design at the last minute which may be very expensive to rectify. Everyone who has taken a close interest in motoring during the last twenty years will remember many mistakes of this kind which have retarded progress and have increased the cost of motoring, because in the long run the user pays for the mistakes of the industry.

The type of man required to deal with the problems which arise during this nursing period is not necessarily the same as in the period of development. In the latter nature is the only enemy, but in the nursing period every user is a potential enemy and has to be treated accordingly. The nurse must therefore possess tact and a knowledge of human nature. He must, in fact, be a diplomatist, but he must also be able to deal with the technical side and accept responsibility where it is called for.

Every firm, even after it has been turning out its products for years, will occasionally turn out one with a serious defect. The prompt recognition of that defect, its admission as a defect and its quick replacement free of cost to the customer makes a friend of that customer for life. On the other hand, failure to recognize the defect, any attempt to throw the blame on to the customer and any parsimonious treatment of the remedy will make an enemy of that customer and his friends, which is much worse than never having had his custom.

The financial success of James Watt's engine was as much due to the nursing of Murdoch during this critical period as to Watt's own efforts in inventing and developing it. In fact the history of James Watt's engine is typical of most successful inventions. We have Watt, the typical inventor, interested only in his science and living for it, in a happy combination with Boulton, its promoter and supporter, and Murdoch, the born nurse and improver — three different types of men all contributing in different ways to one great advance in civilization, possibly the greatest single advance in the history of the world.

Boulton must have been a very patient man to continue for twelve years financing the experiments of Watt before the engine began to be taken up by colliery owners, and when Murdoch, then a youth of 23, joined them in 1777, the work he proceeded to do was of a type for which neither Watt nor Boulton would have been suited. Smiles has written of Watt: "He was not the man to fight the selfishness of the Cornish adventurers." "A little more of this hurrying and vexation," he said, "will knock me up altogether." Murdoch, then only 25, went into Cornwall and gave himself no rest until he had conquered the defects of the engines and put them into thorough working order. He became friendly with the Cornish workmen and engineers. Indeed he literally fought his way into their affections, for one day some half-dozen of the mining captains came into his engine-room at Chace Water and tried to bully him. Murdoch stripped, selected the biggest and set to with his fists. In a few minutes Murdoch, victorious, was shaking hands with the lot of them and they parted the best of friends. I quote this little incident merely as illustrative of the man and of the times and not as an illustration of what is required of a man called upon to nurse an invention in these more peaceable days.

The Inventor and the Promoter

Since I have touched on the chief characteristics required in the nurse of an invention, it may not be inappropriate to refer also to the characteristics of the two other members of the trio.

In the Ordnance Department of the Admiralty there is a colored cartoon of a man with an emaciated body, an enormous head of the encephalitic type, and wearing very concave spectacles, demonstrating a precious invention to a Jack Tar, all muscle and little brain, carrying an enormous spanner in his hand. Below it is the motto from "Our Fathers"—

> The optimist inventor should remember if he can,
> Tho' the instrument is perfect, there are limits to the man.

That cartoon is perhaps typical of the attitude of many men towards the class of men known as inventors. It is an attitude which is as old as invention itself and will persist probably until the end of time. The inventor's point of view, however, is that with the aid of invention there are no "limits to the man." It is his whole object to eliminate the limitations of the human element by giving to man the control through relay mechanisms of power infinitely greater than his own and with little or no expenditure of effort on his own part. The history of the past century shows that he is succeeding beyond belief. His success will continue and is bound to have a marked effect on the type of man of the future.

The highest type of inventor is first of all an artist with a vivid imagination in certain and possibly limited directions. Like the painter he conceives a mental picture and the picture grows as he proceeds to develop it. Like most artists he is unconventional and as a rule diffident except, naturally enough, in his own particular sphere. Unless he possesses also the gift of clear exposition he can not expound his invention and make clear to others the mental picture he has created. Such a man has little chance of working out his ideas and making his inventions commercial propositions without the assistance of a promoter.

The promoter is a man of means and imagination who generally knows something about inventions or the branch of industry to which the invention relates, and is prepared to risk his capital in backing the invention. It is only natural that he should back only the inventions for which he can himself see a field of usefulness and be chary of those which he considers comparatively useless or unlikely to provide him with an adequate return for his risk. The great promoter is the man of vision who is not content to finance minor inventions for improvements in a known industry, but launches forth into the blue in support of an invention, unknown and untried, like the first steam engine or the first iron ship, and cares nothing for the skeptical criticism of the multitude who foretell disaster simply because the invention is something beyond their ken.

Much of the success of the great inventions of history has been due to a happy combination of inventor and promoter, as in the case of Watt and Boulton, and many are the instances where failure has been traceable to lack of this same combination. Its absence must, at the very least, contribute very largely to delays in development and to the impairing of a success which might otherwise have been complete.

INVENTION AND INDUSTRY

The history of the twentieth century shows clearly that invention is the heart of industry, the root of new developments and the source of improved methods of production which have led to cheaper costs and a wider scope in every industry. It has also been the cause of some of the greatest social upheavals and strife. Innumerable strikes have arisen from it, and if there is one lesson in political science more potent than another to be learned from the history of such movements, it is that science is always victorious in the end. Progress may be delayed or an industry may be lost to a country temporarily or permanently by such strife, but the steady advance of the world's progress through the science of invention is certain. One country may lose, but the world will gain in the end. It is only a question of time, and if the leaders of industry, both masters and men, would only recognize this fundamental truth how much faster progress would be.

It must not be imagined, however, that every invention can or, from the commercial point of view, should be introduced into an industry the moment it is made. Quite apart from the time necessarily spent in developing and perfecting the invention, for which purpose many industries have now instituted research departments of incalculable value, it is sometimes found that the occasion is inappropriate or that the time is not ripe for the change involved. The introduction of a new invention or of a new design may involve many complicated questions of policy or finance, because the change may have to be accompanied by heavy sacrifice in other directions, possibly affecting other industries or the public at large. There may have to be heavy scrapping of spare parts, tools and plant. There may also be considerable loss to the customers of the industry through depreciation of the products of the industry already in use, for nothing depreciates a firm's production more rapidly than the introduction of a new and superior model. Manufacturers have therefore, on some occasions, to collect and husband their inventions and improvements after testing their merits and keep them in reserve for a more opportune occasion. The opportunity may occur very suddenly. It may arise through a sudden whimsical change in fashion which no one can explain, or from some other cause which it has been impossible to anticipate, and if a manufacturer has no policy of improvement all worked out and ready to apply he is faced with the awkward alternative of falling behind the times by making no change at all, or of risking his market by adopting some new model which he has not had sufficient time to test thoroughly. The former policy is almost always disastrous and the latter is often worse. Numerous illustrations of both these courses and their results could be cited from any industry. There inevitably comes to every industry a time when radical change is demanded, and the firm which is best prepared for the change reaps the reward of its foresight.

Industry when viewed in its international aspect determines the lives of nations. The nation which organizes its industry most efficiently, which hampers it least and stimulates it most by legislation, or absence of legislation, and by its scientific foresight, is the nation which will prosper most. Since invention is the heart of industry, the enquirer naturally asks: Is this country doing its best to stimulate invention as a means to foster industry? Are the leaders of industry fully alive to the position which invention plays in industrial progress? Have our legislators ever paused to think that their function is only called for because of the progress which has been made by scientific invention, and that without such progress they would be unnecessary; also that in the past legislation has done much to retard progress? A study of the fundamental scientific causes of progress would form a useful addition to the education of legislators.

INVENTION AS A LINK BETWEEN EXACT SCIENCES

It is sometimes stated that the physics of to-day become the engineering of tomorrow. This is a natural development, since the engineer is more concerned than the physicist with the practical application of physical discoveries. But the converse is frequently true, for many physical discoveries and inventions arise in difficulties encountered by the engineer. The science of practical hydrodynamics is a case in point. The mathematical science of hydrodynamics has been of little service to the engineer in the practical problems of the propulsion of ships, in the complex phenomena of vortex motion associated with the flow of water and steam through turbines, or in problems of aerodynamics, with the result that the engineer has had to develop an empirical science of hydrodynamics to supply his immediate needs. A huge mass of experimental results in screw propulsion, in aerodynamics and in hydraulics has thus been accumulated and is now awaiting some discovery or discoveries in mathematics or physics to correlate it all. If vortices could only be dealt with like potatoes or any other form of merchandise, each a complicated physical system in itself but capable of being considered as a unit differing only in mass or in its energy contents, a forward step might be made. The Lanchester-Prandtl theory of lift and drift of aeroplanes is a first step in a particular case of the general problem. Such a discovery, when made, will be bound to lead to further advances and improvements on the engineering side of the subject.

Most discoveries in physics arise from some experimental fact discovered more or less accidentally. The discovery of Röntgen rays was accidental, and the enormous strides which have been made in our knowledge of the atom by J. J. Thomson, Rutherford, Bragg, Born and many other physicists during the last thirty years have resulted from Röntgen's discovery combined with another great discovery in pure thermodynamics, Planck's Quantum Theory, which also arose from an accidental discovery made in the course of experiment. The Reichsanstalt in Berlin had published a family of curves representing the distribution of energy in the spectrum of a hot black body. Professor Wien by trial and error obtained an equation to the family, and the form of this equation was suggestive. Planck in trying to develop this equation from the laws of thermodynamics found that he could only do so by assuming that energy is not indefinitely divisible, and he coined the term "Quantum" to represent the fundamental unit. These two discoveries of Röntgen and Planck form the starting-point of that most important branch of modern physics which has increased our knowledge of the constitution of matter, a science which is just beginning to find its field of application in engineering practice, as in the thermionic valve and the modern power transformers on the same lines. From these and other applications great advances are still to be expected.

In reviewing the discoveries in physics which have had most effect in developing new industries and thus calling forth new inventions, one is struck by the great results in this respect which have arisen from application of the Second Law of Thermodynamics, first stated by Carnot in 1824. Carnot described his ideal heat engine and showed that the efficiency of this engine is independent of the working substance used. Looking back upon the history of the science of thermodynamics of the last century it is unfortunate that no one seems to have employed this statement of Carnot's as a general text, and developed it to find what information could be derived from it by using different working substances and mixtures in order to discover something about all the substances used. Had any one done so, progress might have been greatly accelerated. James Thomson was the first to use this second law to determine the lowering of the freezing-point of water due to pressure. His brother, Lord Kelvin, followed with the application to the change from liquid to vapor. Helmholtz used the voltaic cell as the working substance and determined the temperature coefficient of its electromotive force. Then followed at long intervals the application to chemical changes which have resulted in the modern science of thermodynamic chemistry with which the names of Helmholtz, Ostwald, Nernst, Van't Hoff and Gibbs are so closely associated, and upon which the modern industry of chemical engineering is based. It is a wonderful development to be able to prophesy that under certain conditions a certain chemical reaction will take place, say, that the nitrogen and oxygen of the air will combine at certain temperatures and pressures in a definite proportion, and that the resultant oxide can be recovered and converted to nitrate and used as fertilizer to replace the imported article at an economic price.

The applications of thermodynamic chemistry to explosives enable us to calculate the maximum pressure to be obtained by detonating an explosive, or to calculate the temperatures and pressures throughout the explosion of cordite in a gun from the chemical constituents of the cordite. This possibility has gone far to raise internal ballistics from an empirical science to a branch of natural philosophy.

The advances which have taken place in the commercial development of chemical processes based upon this important new science of thermo-chemistry, although already considerable, are only in their infancy, but the men with the experience gained in practical development are very few; and as the experiments are generally very lengthy and expensive, the development of the industry is necessarily slow. The resultant saving to the country, however, will far outweigh the cost.

Invention forms the natural link between physics, chemistry and engineering, and every advance in one or other of these produces a reflex action on the other. For instance, a discovery in physics which increases accuracy of measurement by providing an indicator more sensitive than any previously known is soon embodied in an engineering instrument carefully designed and manufactured for sale at a price which makes it available to every physicist for use in further research. Thus modern research in physics and chemistry is carried out with accurate apparatus which would be available only at a prohibitive price if it had been made for the particular research alone. The assemblage of apparatus used in a modern research is sometimes like an engineering installation, and is in marked contrast with the cruder, home-made apparatus, designed *ad hoc*, which was common when some of us were students.

The closer the intercourse between the physicist, the chemist and the engineer the greater will be the fertility in invention and the faster the economic progress. The physicist working continually in a laboratory where everything is specially designed to facilitate accuracy of measurement and to eliminate disturbance, is apt to forget how artificial his working conditions really are, and that before any of his beautiful experiments can have a practical application in industry a great deal of invention is required. As an example of successful invention involving an accurate measurement to be made under practical conditions unsuitable to accuracy, I may cite the Barr & Stroud Range-finder, which was invented by two young professors in this university in the days when it was the Yorkshire College. The problem consisted in measuring with great accuracy, say to a second of arc, the small angle subtended at a distant target by a short fixed base placed at the observer. At the time when this invention was made, some forty years ago, the only scientist who normally measured angles to seconds of arc was the astronomer, with his large telescopes mounted on great concrete foundations, with graduated circles from three to six feet in diameter and microscopes to read the scales. It seemed therefore impossible to contemplate the measurement of angles with anything like equal accuracy on board a rolling ship and with no expert operator. Yet the two inventors, seeing an advertisement in the pages of *Engineering* announcing competitive trials of range finders to be held by the war office, took this seemingly impossible task in hand. There was little time to spare. The first instrument was designed in outline in a week and much of the subsequent success is attributable to the sound physical principles underlying this design and to the very ingenious design of all the constructional details, due to the happy combination of an engineer and a physicist both of whom were men of imagination with a flair for invention. Their range-finder was constructed in the university buildings and, to indicate the amount of time that was available, the final adjustment of the instrument was made on a star from the railway platform at Rugby on the way to the trials at Aldershot.

During the trials the instrument worked well at first, but after the sun came out it commenced to read "as thousands of yards ranges which were palpably a few hundred" and the inventors discovered that their beautiful angle measurer was also a thermometer and a sunshine recorder combined. They were not surprised to have it rejected, and they might actually have abandoned it entirely if they had not been asked by the admiralty some time later to submit an instrument for naval use. Then followed ten years of most patient struggle against physical and engineering difficulties, not to mention financial difficulties, for the inventors acted as their own promoters and the financial side of the business must have taxed their resources to the utmost. But at last they succeeded and their range-finder is now the standard instrument in our army and navy and in other countries as well, and has been the foundation of one of our best firms of scientific instrument makers in the country. As student or as assistant I had the honor to serve under both Professor Barr and Professor Stroud, both of them great teachers, versatile inventors and most lovable men, and I am happy to be able to pay this small tribute to them and to their great achievement.

It is unfortunate for Leeds that the transference of Professor Barr to Glasgow in the early stages of this invention should have deprived Leeds of a new industry, and also robbed her later of Professor Stroud as well. Leeds also seems to have been unlucky in regard to at least one other inventor, for Sir Charles Parsons started his life's work in Messrs. Kitson's in Leeds and developed while there his epicycloidal rotary engine, the precursor of the steam turbine which has done so much for British industry in general and for the mercantile marine and navies of the world. I feel sure, however, that Leeds will join with this association, and with this section in particular, in rejoicing that Sir Charles's great work has recently earned for him, as he so rightly deserves, the highest honor that this country can confer on a scientist, the Order of Merit.

I feel sure that the early history of Sir Charles Parsons's work on the rotary engine and on the steam turbine would form a valuable addition to the scientific history of invention, but it has never been written and is passed over in a few lines in the introduction to Mr. Richardson's excellent treatise on the Parsons' turbine. From the little that is written, however, it is easy to see that Sir Charles's task was no easy one.

THE DIFFICULTIES OF INVENTION AND THEIR REMEDY

I wish it to be understood that where I have used the word "invention" I am dealing with the great inventions, and not with the thousand and one minor and comparatively unimportant, though useful, inventions which flood the patent office every year. The latter are generally simple affairs, a minor improvement in a known mechanism or a new way of performing an old simple function. I do not wish to belittle these minor inventions in any way. They serve their purpose in our everyday lives, and all are traceable more or less directly to some major invention of the past, but the distinction which I wish to draw is that in very few cases is their manufacture or development a matter of difficulty. I am, therefore, dealing solely with the big inventions and their development, and it is to the question of the obstacles that are too often encountered in their development that I wish to draw particular attention. This question of difficulty is as old as the history of invention itself, and many of the obstacles have required new discovery or fresh invention to surmount them. I wish now to examine the question of how to eliminate or at least minimize these difficulties that obstruct the inventor and so retard the march of progress.

The first way that suggests itself to me is by means of education. Our educational policy in schools on the scientific side deals with physical laws as facts, and the teacher generally deals only with phenomena with which he can afford to be dogmatic and ignores the enormously greater range of phenomena about which science knows little or nothing. This system inevitably breeds in the student and in the general public the impression that nature acts according to certain definite laws and that there is nothing about these laws which is not known to science. In actual fact the more the scientist knows about these laws the more he is impressed with his ignorance and the failure of science to fathom the complexity of nature. Much of the misunderstanding of invention and its difficulties is due to this method of teaching and will endure so long as that method is maintained. If it were possible to teach physical and chemical science historically much could be done to counteract this injurious effect.

The experimental laboratory tends to modify the dogmatic teaching of the schools because the student there finds out for himself how exceedingly difficult it is to prove experimentally some of the simplest of the physical facts which he learned in the lecture room, and he thus gains a first-hand knowledge of the order of accuracy of physical measurements and of the difficulty in attaining it. Science taught historically would be infinitely more interesting and instructive, but time is the great obstacle. In a recent leader in the *Times* the teaching of the history of science was advocated as a subject for general culture, and comment was also made on similar recommendations emanating from an American writer. Such a study would introduce a better understanding of the science of invention among those who have not given particular attention to it, and the inventor might come to be regarded as a necessary and valuable cog in the wheel of industrial progress and not, as he is too often regarded, as a freak. After all, the inventor is simply trying to make things simpler and easier and safer for his fellow men, and he is succeeding beyond belief. Surely that object is worthy of recognition and encouragement.

A second possible remedy to encourage invention and minimize its difficulties is by means of legislation. I hesitate to enlarge on this point because the question of patents is a controversial one among scientists, and between inventors and the outside public, but it seems to me anomalous that a man who makes an epoch-making invention which is going to revolutionize an industry and add millions to the wealth of the nation receives exactly the same degree of protection for his invention as the man who invents a new kind of shirt button. In the first case the invention will take years to develop and may cost thousands of pounds in the process, and by the time it reaches the productive stage the patent may have expired. In the case of the shirt button, a term which I use figuratively, there are no difficulties to overcome, practically no expense, no loss of time and a clear sixteen years' trade monopoly. I know that a patent is granted only for a new method of manufacture which has to be described in the patent specification so that any one skilled in the art may put it into practice at once. In simple inventions which form the subjects of the great majority of patents this is actually the case, but there are undoubtedly cases where what appears to the inventor to be a practical scheme and was honestly described by him as such, proves subsequently to be difficult to put into effect on account of technical difficulties which he had not foreseen, and the remedy for which may not be patentable. Such obstacles and their remedy can not be recorded in the patent because they have not been encountered when the specification is written. If it be argued that the inventor should not apply for a patent until the practical application of the invention has been achieved, then the inventor argues in reply that by delaying his application he is incurring the risk of having someone else forestall him, by fair means or foul, and so lose his trade monopoly. Under our present system a period of nine months is allowed between filing the provisional and complete specifications, which period, while ample in the case of most inventions, is inadequate for full investigation of the really great inventions, and it is to this difference between major and minor inventions that I wish to draw attention.

In America it is possible for an applicant for a patent, by filing periodical amendments of his specifications, to keep the application pending in the patent office for a number of years, during which he can be developing the invention and adding to the specification any further explanations which may be called for in the light of the experience gained. Then when the patent is eventually issued it runs for seventeen years from the date of issue, whereas a British patent dates from the date of application. In addition to this, an American patentee, on any question of priority of invention, is allowed to produce any evidence that may be available to show conception of the invention up to not more than two years anterior to the date of his original application. In this way an American inventor can spend several useful years perfecting his invention before his patent is granted, while the British inventor has often to watch the most useful years of his patent being eaten up in unproductive development. I admit that the American system has drawbacks from the point of view of an industry, but it has certain undoubted advantages, and I suggest that our system does not meet the needs of great inventions, between which and the ordinary minor inventions there ought in my opinion to be some discrimination. Merely as a suggestion, I see a possible solution in an extension of our present system of granting patents of addition, that is, a patent for an improvement on a prior patented invention, the patent of addition being granted during the lifetime of the original patent and running coterminously. If a patent of addition could be granted to an inventor in approved cases on production of evidence of genuine difficulties encountered and successfully overcome, these difficulties and their remedy to be fully described in the patent for the guidance of the industry, and if this patent of addition could be made valid for a definite term of years, one of the main fears of a patentee would be overcome.

It will be noticed that in this last suggestion I have stipulated that the specification of a patent of addition, such as I suggest, should contain not only a description of the finished invention but of all the difficulties encountered in its production and the steps taken to surmount them. In fact, it is mainly for this reason that I make the suggestion at all. I am trying to devise a means to prevent future inventors and industry from being handicapped in a way that has been all too common in the past. I have already touched on what must be the large volume of valuable scientific information that has been lost through lack of records of past difficulties. Patent specifications are in many cases the sole record of inventions, yet in the cases of the type I have mentioned they tell us nothing of the difficulties simply because the specification is written before the difficulties are encountered. I, therefore, suggest that if any additional protection be given to a patentee in virtue of work done in converting his invention into a practical mechanism in face of unsuspected obstacles, the grant should be absolutely conditional on his placing on public record for the guidance of others a complete history of his efforts so that no one may have to contend with the same troubles again.

I have one more suggestion to offer in closing, a suggestion which touches this association and kindred bodies more intimately. On this question of assisting future inventors by increasing the store of knowledge at their disposal, I see a possible sphere of usefulness for this association and kindred institutions by encouraging the great inventors of today to place on record and publish through the medium of the association or institution an account, even a brief one, of the main historical features of their inventions. If considerations of patents or of personal diffidence make it undesirable to publish these records at the time they are written, that need not impede the scheme, as publication could be made subsequently at a more convenient time or, say, after the inventor's death. The main thing is to have some authentic record from the inventor or discoverer himself recording the origin, growth and development of his idea, the difficulties that beset him and the manner in which they were overcome. Nor do I think we should stop there. In my opinion too much attention has been paid in the past to success and too little to honest failure. It is one of our human frailties to look with something of contempt on the man who has failed to reach his goal, but this is not the attitude of the great minds, nor should it be the attitude of modern science. On one occasion Lord Kelvin was shown a report by a professor on a research carried out by a research scholar, in which the professor had made some rather contemptuous remarks on the results attained because these results were mainly negative. Kelvin was highly indignant. All he looked to was the fact that the young scholar had done his best on a subject which merited investigation and in face of undoubted difficulties, and it amazed him that any scientist should speak slightingly of the results, simply because they were negative, when the real thing of value was the earnest and diligent search after truth.

If therefore my suggestion be adopted by this association, would it not be in the best interests of science to remember the failures as well as the successes, and to encourage all serious workers in important fields of research to furnish in the common cause a record of their work, even when their aim has not been achieved, giving a faithful account of all the difficulties and all the efforts made to surmount them? Who knows but that many of the so-called failures of yesterday may only be waiting for other hands to-day to carry them on to a greater success than the world has yet known? Left to themselves they will lie in oblivion, yet, for all we know, two of them may fit together and provide the answer to one more of the riddles of the universe.

Knowledge forms the working tools of science, and my proposal is in no way aimed at giving the scientific workers of to-morrow an easy task. They will probably have a far more difficult task than ours, but I do not think it fair to condemn them to spend part of their time in a preliminary and possibly fruitless search for tools which we have forged and hidden.

"As one lamp lights another, nor grows less," science of to-day will partly fail in its clear duty if it fails to pass on to to-morrow any of the knowledge which it has been privileged to acquire, or if it forgets that it is for to-morrow, rather than to-day, to assess the true value of to-day's success and failure.

THE ENZYME THEORY OF ANTIBODY FORMATION[1]

By W. H. MANWARING, M.D.
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THE most important factor in the development of any science is the truth or falsity of the basic concepts in that science. In no science is this better illustrated than in the fundamental sciences underlying medical practice, for example, the primitive belief that still dominated European medicine as late as the opening centuries of the Christian era, that most diseases are due to the entrance into the human body of devils, demons or other evil spirits, the later metaphysical deduction that transmissible diseases must necessarily be due to the entrance into the human body of noxious vapors or miasmatic gases, and the concurrent and later religio-therapeutic dogmas that material agents are divinely marked by shape, color or other easily recognizable characteristics for man's therapeutic guidance. Each of these basic assumptions has given rise to logical and consistent methods of medical practice. Each has led to the discovery of valuable therapeutic methods. These discoveries, however, we now regard as accidental empirical findings that were made in spite of the handicap of erroneous bases for therapeutic deduction.

I have thought that it might not be without interest to workers in other scientific fields if I should outline very briefly and in non-technical language the generally accepted basic concepts of the present day in some one field of practical medicine, with an inquiry as to whether or not the wide acceptance of these concepts is an aid or a handicap to medical progress. I have selected as this illustration the generally accepted assumptions at the present time as to the nature of certain highly specialized defensive chemical substances in blood serum.

CIRCULATING CHEMICAL DEFENSES

Our knowledge of the existence of these highly specialized circulating chemical defenses dates from the closing decade of the nineteenth century. It was found at this time that animals given repeated injections with minute, almost non-toxic doses of certain extremely poisonous chemical substances, will in time develop a high tolerance for these poisons. In extreme cases such an artificially immunized animal may be injected with ten thousand times the usual lethal dose of the poison, without showing appreciable toxic symptoms. It was further found that a certain amount of this acquired immunity and at times a high degree of immunity, can be transferred from such an artificially immunized animal to a normal animal by a serum transfer. The new, increased or altered serum component or group of components responsible for this transfer was named antitoxin.

The poisons stimulating the production of circulating antitoxins are all of them complex poisons of biological origin. Among them are snake venom, extracts from poisonous mushrooms, and highly toxic products formed or liberated by the growth or disintegration of certain pathogenic microorganisms in artificial culture media. It was found that serum antitoxins are specifically adapted to the poison stimulating their production, a serum giving complete protection against a hundred lethal doses of one poison, for example, usually giving no demonstable protection against other poisons, even poisons of very similar biological origin.

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[1] For a technical presentation of this topic see: *Jour. Immunol.*, *12*: 177, 1926.

It was soon found that in addition to antitoxins numerous other equally important specific substances can be induced or increased in blood serum by other methods of immunization. By the injection of foreign cells of animal, plant or microbic origin, for example, the injection of foreign leucocytes, foreign spermatozoa, pollen, yeasts or bacteria, there are induced in the serum new or heightened powers to agglutinate these foreign cells. In extreme cases the foreign cells are killed and completely dissolved or digested by such sera. This gave rise to such terms as specific cytagglutinin, specific cytocide and specific cytolysin. By the injection of foreign proteins of animal, plant or microbic origin, such as egg white, gluten or bacterial extracts, there are induced in the serum new or heightened powers to cause precipitates when the serum is mixed with these proteins. This gave rise to the term specific precipitin. There are also other new or increased specific serum components or properties that are demonstrable with more complex technical methods. All these new, increased or specifically altered serum components are usually classed under the generic title, specific antibodies.

During the opening decade of the present century a second and equally important body adaptation was discovered, the power of the body, following certain special methods of inoculation or injection, to develop what is apparently the exact opposite of heightened resistance, to become specifically hypersensitive. In extreme cases such an artificially sensitized animal can be killed in from three to five minutes by an injection of a hundredth part of the usual lethal dose of the sensitizing agent. Egg white, for example, which is practically non-toxic for normal animals, has the toxicity of prussic acid for an egg-white sensitized animal. It was found that a certain amount of this acquired hypersensitiveness can be transferred from an artificially sensitized animal to a normal animal by a serum transfer. For lack of a better term, the new, increased or specifically altered serum component or group of components responsible for this transfer is often referred to as a specific sensitizing antibody.

The most important fundamental problem in immunology during the last three decades, therefore, has been the determination of the nature of these new, increased or specifically altered serum components, together with a determination of their method of formation and physiological rôle in the animal body, and their possible agricultural, industrial and clinical applications. It was soon found that but little could be accomplished by direct chemical methods. Specific antibodies so far as studied are relatively non-dialysable. They are, therefore, presumably all of them colloids, or at least substances closely associated with colloids. On fractionation of the serum colloids most of the specific antibodies are precipitated with the globulin fraction. But by no known chemical method can they be isolated from these globulins in a state of even approximate purity.

From indirect experimental and clinical evidence, however, an extremely ingenious theory was developed as to the origin and nature of these circulating chemical defenses. This theory was promptly endorsed by the medical profession as a whole. For three decades it has been the sole basis for theoretical deduction and clinical interpretation by the majority of practitioners and laboratory workers. The essential features of this theory were developed by Paul Ehrlich.

THE EHRLICH HYPOTHESES

The Ehrlich theory as to the origin and nature of specific antibodies is based on a number of major and minor hypotheses, each hypothesis, of course, being supported by experimental and clinical evidence. The three major hypotheses are:

(a) That the specifically altered powers of blood serum resulting from natural infections and from artificial immunizations are due to an increase in the amount of certain normal highly specialized serum components, usually present in minute, unrecognizable traces.

(b) That these highly specialized normal serum components are internal secretions that are given off into the body fluids by the fixed tissues and wandering cells of the body.

(c) That all phenomena of specific immunity and specific hypersusceptibility and all related test-tube reactions are due to changes in the amount of these highly specialized normal internal secretions, or to changes in their topographical distribution in different tissues and fluids of the body.

In other words, Ehrlich assumed as his major premise that in specific immunological adaptations we are dealing solely with quantitative changes in certain hereditary, preformed, highly specialized, defensive chemical substance, normally present in the body.

Ehrlich's minor hypotheses deal mainly with the method of formation and liberation of these highly specialized defensive chemical substances by the fixed tissues and wandering cells of the body. These hypotheses are based on the specific receptor theory of cell nutrition, which was quite generally accepted by physiologists during the middle decades of the nineteenth century. The receptor theory of cell nutrition assumes that each cell of the body is provided with numerous highly specialized "food receptors," each receptor being a superficial atomic group or side-chain of the living cytoplasm, having a highly specialized chemical affinity for a certain food material. By means of these highly specialized side-chains or receptors foods were believed to be selected from the blood stream and brought into close chemical union with the cytoplasm. Ehrlich assumes: (d) that some of these highly specialized food receptors have accidental affinities for certain injurious agents; and (e) that the toxic action of these agents is due solely to their chemical union with these accidental affinities.

Ehrlich further assumes: (f) that a side-chain or receptor having this accidental affinity is permanently injured or denaturized by its chemical union with the injurious agent; (g) that the resulting denaturized side-chain or receptor is eventually cast off by the living cell, and (h) that the cell now has the power to regenerate a new side-chain or receptors of identical chemical structure.

In response to repeated injections with the same injurious agent or to a sufficiently large single dose of that agent, Ehrlich assumes: (i) that the resulting side-chain regeneration is overstimulated, more than one receptor being formed to replace the one denaturized and lost; (j) that the superfluous side-chains or cell receptors thus formed are in time cast off by the living cell and set free in the body fluids, and (k) that these cast-off superfluous side-chains or receptors are the specific defensive internal secretions with which we deal.

To account for their defensive action, Ehrlich assumes: (1) that these cast-off receptors still retain their original accidental affinities for the injurious agent, and (m) that their defensive action is due solely to their chemical union with the injurious agent in the body fluids, thus preventing its union with living cells.

To explain certain minor immunological phenomena Ehrlich made a number of minor assumptions, such as: (n) that free or circulating receptors still retain their original affinities for their cells of origin, and have a tendency to reunite with these cells, and (o) that there are differences in the number, type, avidity and valence of the receptors normally present in different cells and in different animal species.

THE EHRLICH THEORY AS AN EXPLANATION OF KNOWN IMMUNOLOGICAL FACTS

The theory thus formulated logically explained and coordinated all immunological facts known to Ehrlich. With very slight variations in detail it is in accord with most of the immunological facts developed since his time. The susceptibility of certain animal species for certain injurious agents, for example, is logically explained by this theory on the assumption that certain vital tissues in these animal species contain an unusually large number of food receptors having accidental affinities for these injurious agents, or, by the assumption of vital tissue receptors of unusually great avidity for these agents. The insusceptibility of other animal species for the same agents is a logical result of an assumed paucity or low avidity of the same receptors. Or it may be explained as a result of an assumed large number of highly avid receptors for this agent in physiologically inert tissues, thus diverting the injurious agent from vital parts.

Under the Ehrlich theory, the development of specific hypersusceptibility following certain methods of immunization would be a logical result of a local multiplication of these accidental affinities in vital tissues, with little or no liberation of defensive receptors in the body fluids. A further multiplication of the same receptors with an adequate number set free in the body fluids would change the hypersusceptibility to an immunity. The serum transfer of immunity from one animal to another would logically result from a sufficiently large number of these freed receptors in the circulating blood. The serum transfer of hypersusceptibility would logically follow a small number of freed receptors in the blood, all or most of the transferred receptors becoming attached to the body cells of the recipient animal, thus increasing their affinity for the injurious agent and leaving few if any defensive receptors in the body fluids. All specific test-tube reactions would be logically explained as a result of chemical union between the injurious agent and free receptors, the details being determined by the number, type, avidity and valence of these receptors.

The Ehrlich theory, of course, was not without its critics. Criticism, however, was usually directed against some minor, non-essential feature of the theory rather than against the theory as a whole. For example, there was at one time considerable discussion as to whether freed receptors and injurious agents unite to form dissociable or non-dissociable chemical compounds, a question of considerable clinical significance. There was difference of opinion as to the exact sequence of the reactions that take place when two serum components cooperate in their defensive action against the same injurious agent. Also different interpretations of certain apparent variations from the law of multiple proportion in certain serum reactions.

With such minor reservations as to detail, however, the Ehrlich theory was promptly endorsed by the medical profession as a whole. For three decades it has had a prominent place in elementary text-books in bacteriology and clinical pathology, and has been the generally accepted basis for immunological deduction and clinical interpretation. Yet, I believe there is hardly an element of truth in a single one of the dozen or more basic hypotheses incorporated in this theory.

CRITIQUE OF THE EHRLICH THEORY

My conviction that there is something radically wrong in our accepted basic concepts arose from a consideration of the almost universal failure of therapeutic methods based on these concepts. According to the Ehrlich theory, for example, any specific chemical substance that can be caused to appear or to increase in blood serum as a result of natural infection or artificial immunization is necessarily a specific defensive substance. It is only necessary to obtain this substance in sufficiently large quantities to have a valuable therapeutic agent. Specific antibodies may be readily induced with any pathogenic microorganism. Yet, in spite of millions of dollars spent in research and ten million in the commercial exploitation of antisera, they have been lamentably unsuccessful as therapeutic agents, except in a small group of relatively unimportant diseases. A percentage of success not much greater than the few hygienic successes developed as a result of logical deductions from the medieval miasmatic theory of disease production.

This failure is usually explained as a result of the impossibility of preparing antisera of sufficiently high specific titre, or as due to an assumed antagonism between the human body and foreign antibodies. It is equally logical, however, to assume that the failure is a logical result of some fundamental error in our basic assumptions.

During the last twelve years, therefore, I have been engaged in a series of immuno-physiological studies designed to test the truth or falsity of the fundamental Ehrlich assumptions. The physiologic reaction used in most of these studies has been the precipitous and pronounced fall in arterial blood pressure during the specific hypersensitive reaction in certain animal species, together with the accompanying tetanus of certain smooth muscle structures. This work has yielded a mass of experimental evidence directly contrary to and irreconcilable with the Ehrlich theory. I will briefly outline four typical findings:

(a) The Ehrlich theory assumes that specific immunity is due solely to circulating defensive chemical substances. Yet if the blood of a hypersensitive dog is removed and replaced with the blood of a dog immunized against the same injurious agent, the transferred immune blood on immediate physiological test gives no protection whatsoever to the specifically hypersensitive tissues.

(b) According to the Ehrlich theory the blood-free tissues of immune animals are necessarily hypersensitive, at least in the early stages of immunization, due to an increased number of specific receptors in these tissues. Yet the blood-free lungs of immune dogs show no suggestion whatsoever of a specific hypersensitiveness on perfusion with Locke's solution containing the specific injurious agent.

(c) According to the Ehrlich theory the blood-free tissues of hypersensitive animals have an increased affinity for the specific sensitizing agent. Yet repeated perfusions of blood-free organs of hypersensitive animals with perfusion fluids containing even minute traces of this agent give no demonstrable reduction in the concentration of the sensitizing agent in the perfusates.

(d) According to the Ehrlich theory

specific antibodies are necessarily qualitatively identical in all methods and at all stages of sensitization and immunization with the same injurious agent. The only conceivable differences are changes in amount and in topographical distribution. Yet, the blood of a hypersensitive dog will render a transfused normal dog specifically hypersensitive, while fractional transfusion from an immune dog will give no suggestion whatsoever of transferred hypersensitiveness.

A dozen or more irreconcilable results of this type have convinced me that the Ehrlich conceptions of the origin, nature and physiological rôle of specific antibodies are erroneous.

THE PROPOSED ENZYME HYPOTHESIS

Of course, one who expresses disbelief in the accepted tenets of a great science is at once challenged to suggest more plausible tenets. While not prepared to formulate a detailed theory, I believe I can predict the two main facts that will be the basis for this theory. Cell nutrition is currently believed to be mediated largely through enzymes, enzyme activators and enzyme inhibitors. The main enzymes concerned in cell nutrition are of two types; hydrolyzing enzymes and synthesizing enzymes. These enzymes with their activators and inhibitors are demonstrable in both cellular contents and body fluids. I believe specific antibody formation will in time be shown to be one of the important functions of these enzymes.

The chemical substances stimulating specific antibody formation are mainly complex foreign proteins, or protein-lipoid or protein-carbohydrate compounds. According to the enzymes theory of antibody production, complex foreign proteins introduced into the animal body are subjected to two main enzymic processes. First, to a series of hydrolytic cleavages, supplemented by colloidal dissociations, ionic dispersions and the like, by means of which the complex proteins are broken down into simpler components. The stages and sequences in this proteolysis are presumably similar to those in gastro-intestinal digestion, the details, of course, varying with dosage, portal of entry and topographical distribution. Many of the earlier cleavage products would presumably have the same specificity as that of the original protein, since it is known that complex proteins subjected to artificial tryptic digestion remain specific till reduced to relatively simple digestive products.

The second enzymic process would be a series of chemical syntheses, coagulations, conjugations, adsorptions and the like between the original foreign protein or its cleavage products and normal humoral and cellular components. The details here also would vary with dosage, portal of entry and topographical distribution. Many of the earlier conjugation products would presumably retain their original specificity. Later products might be less highly specific, or even non-specific. Certain conjugates might even acquire a new specificity, setting up a second series or second wave of specific immunological adaptations in the body.

Some of the humoral or cellular products resulting from this combined hydrolysis and synthesis might conceivably have a specific protective action for the body as a whole. Others might conceivably increase specific susceptibility. Still others might cause non-specific variations in bodily resistance. Many of the products, of course, might be physiologically inert.

CONFIRMATORY EVIDENCE

During the last two years we have obtained experimental evidence in harmony with this conception of the dominant mechanism of antibody formation.

I will briefly outline four typical findings:

(a) If a massive dose of a non-toxic foreign protein is injected intravenously into a normal dog, and if from one to six hours later a quantitative blood transfusion is made from this dog into a partially exsanguinated hypersensitive recipient, the transfused hypersensitive dog will be thrown into a typical hypersensitive reaction. The reaction in this dog, however, is in most cases twice as severe as the reaction produced by the control injection of the calculated amount of specific foreign protein contained in the transferred blood sample into a second hypersensitive dog. Furthermore, this increased toxicity is specific, since the transferred blood has no recognizable toxicity for normal dogs. The simplest explanation of this increased specific toxicity is the assumption that the number of specific foreign protein molecules has been doubled in the transfused blood as a result of contact with normal cells and body fluids. Such a multiplication of specific protein molecules is in harmony with the predicted hydrolytic cleavage of the enzyme theory.

(b) If, instead of making the transfusion at the end of one to six hours, the transfusion is delayed till the end of four days, the transfused blood is invariably non-toxic for the hypersensitive recipient. Titration by means of rabbit precipitin shows that, within the limits of the experimental error, there is but little decrease in the amount of specific foreign protein in the transfused blood at this time. This finding is in harmony with the predicted denaturization of specific foreign protein as a result of contact with normal tissues and body fluids.

(c) If the urinary bladder of a normal dog is transplanted by blood-vessel anastomosis into a hypersensitive recipient, and if the resulting composite animal is now thrown into the hypersensitive reaction, the transplanted normal urinary bladder is thrown into a prolonged tetanus. Physiological analysis has shown that this tetanus is due to histamine-like[2] substances explosively formed or liberated by the hypersensitive liver. The bladder of an immune dog similarly transplanted is wholly insusceptible to this histamine-like hepatic product. Moreover, this acquired insusceptibility is specific. This finding is in harmony with the predicted production of a secondary specificity in protein denaturization products as a result of contact with fixed tissues and body fluids, with the setting up of a secondary wave of specific immunological adaptations.

(d) Probably our most suggestive finding is the observation that this acquired histamine-like insusceptibility can not be transferred from an immune dog to a normal dog by even massive immune blood transfusion. This finding is in harmony with the predicted specific intracellular antibodies chemically distinct from the circulating antibodies.

THE ENZYME THEORY AS AN EXPLANATION OF KNOWN IMMUNOLOGICAL FACTS

With but little juggling with minor hypotheses, the enzyme theory of antibody production will explain and coordinate all known immunological facts directly or indirectly dependent upon specific antibodies. Antitoxins, for example, would become relatively stable synthetic products formed by a conjugation between toxins or their cleavage products and normal or denatured serum proteins. If we assume this conjugate to be slightly dissociable, the non-toxic dissociation fragment would be gradually increased in the body as a result of its repeated conjugations with

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[2] Physiological sense.

new serum proteins. This would lead in time to an almost complete suppression of the toxic dissociation fragment by the simple laws of mass action. Toxin added to an antitoxic serum would be suppressed by union with this preponderant non-toxic dissociation product.

Unstable or highly dissociable serum conjugates might readily lead to explosive colloidal readjustments in body fluids on the injection of the immunizating agent. Such an explosive readjustment is one of the well-known humoral factors in the specific hypersensitive reaction. Unstable or highly dissociable conjugates between the extraneous agent and cellular proteins might readily lead to explosively increased cell permeability, a second well-known factor in specific hypersensitiveness. Later, stable or relatively non-dissociable cellular conjugates might account for the disappearance of this increased cell permeability in immune animals.

The Enzyme Theory in the Interpretation of Clinical Data

The general acceptance of the enzyme theory of antibody production, however, would necessitate a radical reinterpretation of much of the accumulated laboratory and clinical data of the last three decades. Test-tube reactions could no longer be assumed to be a reliable measure of specific resistance. This would readily account for the puzzling lack of parallelism often observed between serum reactions and clinical outcome, and between specific titre of an antiserum and its therapeutic effects. Specific intracellular antibodies chemically distinct from the humoral antibodies might readily account for the high organ-specificity of certain pathogenic micro-organism, and for variations in immunizing power with different methods of injection, both of which are almost inconceivable with our present theories. Secondary relatively specific or non-specific antibodies might readily account for non-specific serum reactions, so difficult to explain under the Ehrlich theory.

Conclusion

I believe the enzyme theory is to-day our most promising working hypothesis as to the immediate physiological mechanism of antibody formation, and that as such it is entitled to serious consideration. Nevertheless, I believe the medical profession owes a great debt to the genius of Paul Ehrlich for his clever specific receptor hypothesis, which has stimulated and coordinated a generation and a half of serological investigation. This debt will not be lessened, even though future generations may look upon all practical results that have come from this investigation as accidental empirical findings that were made in spite of the handicap of an erroneous basis for theoretical deductions.

THE SUN'S HEAT[1]

By F. E. FOWLE

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THE savages worshipped the sun. The prehistoric Indians oriented their temples according to its rising and setting; knew that when it set far north, their days were warm, when far south, cold. There come years of exceptional cold and heat. Since the sun's changing position in the sky causes the cold or heat of winter and summer, why not look to it also as the cause of the other extreme temperatures? We know that in the remote geological past exceptionally warm and moist climates prevailed, with intervening periods of exceptional cold—ice-ages; were these due to changes in heat sent out by the sun? Will there be recurrences of such periods? At present we can only say, "possibly," but further study may bring a more definite answer.

The Astrophysical Observatory of the Smithsonian Institution maintains a group of astronomers on a mountain peak (altitude 5,200 feet) in the desert region surrounded by the Hottentots of South Africa, a group on Mount Montezuma (9,500 feet) in the nitrate desert high up in the Andes of Chile, and yet another group on a peak (7,500 feet) of the Rocky Mountains, near Death's Valley in California.

In each of these stations we have observers to study the heat of the sun. Such deserted, dry, high-altitude places have been chosen in order to be rid of the disturbing effects of dust, smoke, water-vapor, and, as far as possible, of the air itself. Further, above these peaks the sky is practically cloudless and rain almost never falls.

That heat comes directly to us from the sun is almost self-evident. You have but to step from the open sunlight into the shade of a tree to realize it. The effect of the air about us, serving to diffuse the light and heat, becomes evident in the greater contrast between light and shade on a high mountain, say one a mile or so in altitude. There it may be uncomfortably cool under a tree and uncomfortably hot in the direct sunlight.

We are interested in measuring not only the heat *received* from the sun but also whatever losses this heat has suffered in coming to us. We thus find that not only does the heat *received* from the sun alter, but after having eliminated the losses due to the various hindrances to its passage through the air—the dust, moisture, volcanic dust, etc.—the heat emanating from the sun itself changes in amount.

The knowledge of this variation in the heat *sent* us from the sun, together with our studies of the behavior of the air in allowing this heat to pass through it, we hope may some day lead to seasonal weather predictions. We also investigate the passage of this heat back again out into space. Since, from year to year, the average temperature of the earth remains much the same, the earth must, on the whole, lose as much heat as it receives. It is true that with the oncoming of summer, a little is stored each day, so that day by day it becomes warmer. But to make up for this gain, as winter approaches, a little more is lost each day than is received.

The instrument used to measure the heat received from the sun is extremely simple, although very great care is needed for accurate measurements. It

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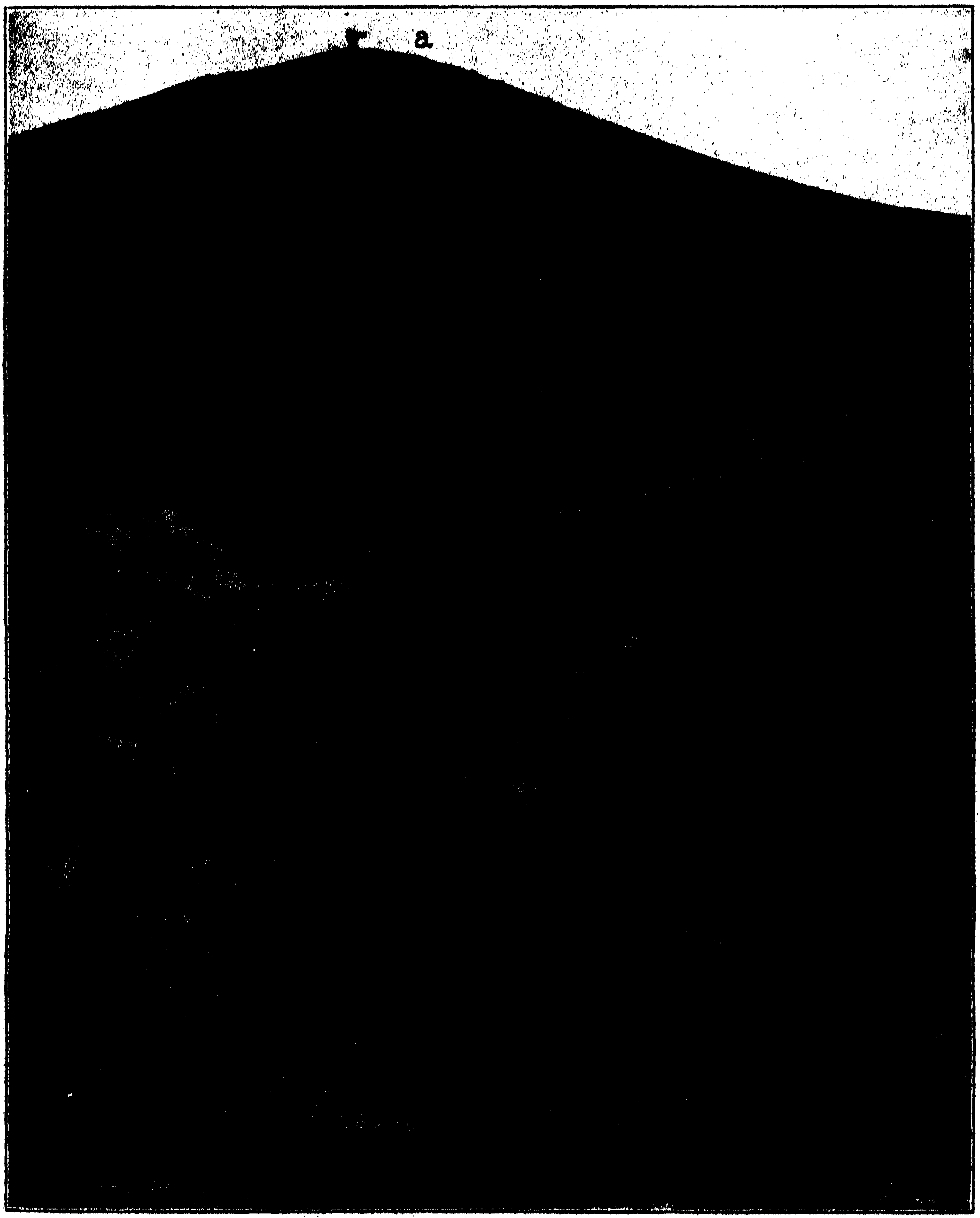
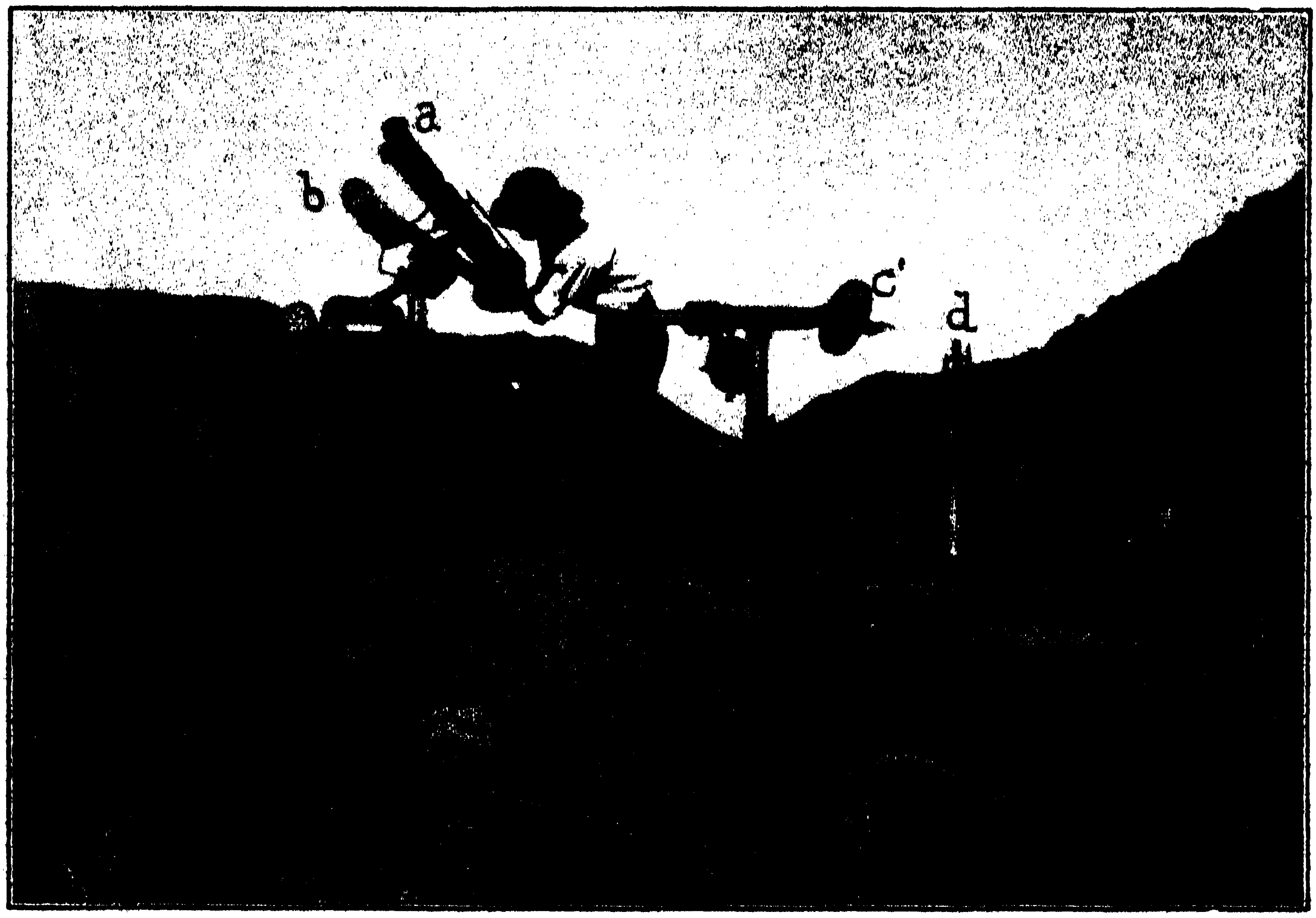
[1] One of the Smithsonian series of radio talks arranged by Austin H. Clark and broadcasted from Station WRC, Washington.



STATION AT MONTEZUMA, CHILE

Located in the Andes, altitude 9,500 ft.; a, windmill for power, charging storage battery, etc.; observing station; b, observers' quarters.

is a blackened silver disk about the size of a dollar, although somewhat thicker, so that a thermometer may be inserted in a hole bored in its edge. The disk is shaded by a screen, then exposed directly to the heat from the sun for one hundred seconds, and again shaded. The difference of the thermometer readings shows the amount of heat received. Among the many refinements necessary is the enclosure of the silver disk to protect it from air-currents, the heat from the surroundings (including the observer's body), the heat from the sky, etc.



OBSERVER AT BRUKAROS, AFRICA

ALTITUDE 5,200 FT., OBSERVING WITH TWIN SILVER-DISK PYRHELIOMETER, a; b IS PYRANOMETER USED IN MEASURING TRANSPARENCY OF SKY; c, c′, MIRRORS OF COELOSTAT FOR SENDING SUN'S HEAT INTO OBSERVATORY IN CAVE OFF TO THE RIGHT OF PICTURE; d IS THEODOLITE FOR MEASURING THICKNESS OF AIR-PATH OF SUN'S RAYS.

The readings from this instrument, which we call a silver-disk pyrheliometer and which is so placed as to look directly at the sun, show two results which to many would be surprising:

(1) When the readings are corrected for the losses suffered by the heat on its way to us from the sun, in general they will be the greatest about January 3, when they will be nearly 7 per cent. higher than at their lowest, about July 3. This is because the sun is nearest us in the early part of January.

(2) On a high snow-capped mountain you might expect the instrument to read lower than on a hot desert at sea-level. But, no, it indicates more heat from the sun. This is because there is less air above the high mountain to hinder the heat in its passage from the sun to the instrument. Thus, despite the cold surroundings—the cause of which is quite another story—the sun shines on the top of a high mountain with great intensity. Mountain climbers are well aware of this and protect their heads thoroughly lest the shaded size freeze and the sun side blister!

Heat from the sun may be thought of as "high-potential" or more strictly "high-temperature" heat. About 99 per cent. of such heat can pass directly through glass after allowing for the portion which is reflected by the glass. Heat from lower temperature sources can not thus pass directly through glass without hindrance. The glass is first warmed by the heat which sticks in it and then slowly oozes out by conduction. The *sun's* heat leaves very little in the glass. All this is taken advantage of in greenhouses or hothouses. The sun's heat passes through the glass roof, the darker earth absorbs it, and, like a trans-former, steps it down to a lower potential or temperature. It is then given back through the air in the form which will not pass out so readily through the glass. The heat comes in as if in an express train and goes out on an extremely slow accommodation train.

In warm sunny climates water for the bathroom is often contained in a tank on the roof where it may be covered with glass and thus heated by the sun.

Herschel cooked eggs by a somewhat similar device, a so-called hot-box. A shallow flat circular box is taken—I have in mind one about two feet in diameter—made air-tight, its inside bottom blackened, its sides within and without and the outside bottom painted white, then padded without at its side and bottom with a sufficiency of some very bad conductor of heat like feathers or diatomaceous earth. The front is covered with a thick clear piece of glass tightly clamped on and then the front of the box is directly set towards the sun. The inclosed space, in which the eggs should be placed (it might be well to blacken the outside of the eggs so they would absorb the heat more thoroughly), becomes a very efficient hot-box and may easily reach the temperature of boiling water.

The heat from the sun is immense and profligate in quantity. Each square centimeter of the earth's surface receives every minute enough to heat a cubic centimeter of water about 2° F. That means that the heat received on an ordinary clear day over a square yard would be enough in ten minutes to boil one quart of water. This would surely be worth saving if a process could be invented to store it.

Most of you—perhaps excepting those who have been apartment dwellers all your life or who have never been in the kitchen—know that the water for the service of a house is heated by running it through a pipe placed in the coal-box of the kitchen stove or the fire-box of the furnace and is then stored in the hot-water tank.

Dr. Abbot has considerably elaborated this scheme. Instead of passing the pipe in which the water is to be heated through one of the sources of heat just mentioned, it is blackened and run along the focus of a large cylindrical mirror. The focus of a cylindrical mirror lies along a line instead of at a point as with a spherical or ordinary mirror or lens. There is so much heat thus collected when the sun shines on the mirror and is focussed on the pipe that the water would soon be steam. To avoid the difficulties and danger from steam an oil is used which can be heated to a much higher temperature than water before it boils. This oil, when so heated, rises into and is stored within a tank carefully insulated from heat losses. As the oil gradually cools in the tank it flows down again in circuit through the heater pipe in the sun's focus.

Within the storage tank there is a recess or oven contrived, which, surrounded by the hot oil, hotter than boiling water if need be, acts like a fireless cooker. Within this bread and meat have been baked and fruit preserved. Boiling water may be had by drawing water from another pipe running through the tank of hot oil. This solar-heater has already been very successfully used on Mount Wilson in California by Dr. and Mrs. Abbot and merely awaits further development and utilization.

An ordinary spy-glass may be used for studying the surface of the sun. Do not look at the sun through it, your eye might possibly be burned up! We received a letter from a man who had foolishly looked at the sun too long with his naked eye and wished to know what were the red wheels he kept seeing going around in his head. He certainly had "wheels in his head." The image of the sun formed by a ten-inch lens of short focus is so intense that a fly passing in-

SOLAR COOKER ON MOUNT WILSON, CALIFORNIA

ALTITUDE 1 MILE; a IS CONCENTRATING MIRROR; b IS TANK FOR STORING HOT OIL; c IS DRIVING MECHANISM TO KEEP MIRROR POINTED AT THE SUN.

advertently through the focus would immediately be turned into gas. We used to use this principle to kill wasps about our telescopes, in self-defense, of course. We would set a mirror with its focus in the air right in front of the wasp's nest. A wasp coming out would pass through it, be vaporized, sparked and exploded and pass into eternity, its utter annihilation an unsolved mystery to the subsequent victims who followed in his path to find him! Many a man has lit his cigarette with his small pocket burning glass. So avoid looking at the sun, even with the unaided eye, which is itself a lens.

In studying the sun an image is usually thrown by the telescope on a screen and the disk thus formed utilized. Any one possessing an ordinary spy-glass may obtain such an image. Choose some open window through which the sun is shining. With paper or cloth shut out the light as much as possible, leaving only a small aperture through which may be passed the objective of the spy-glass. Set the spy-glass so that the light from the sun passes straight down through the tube. Then move the eye-piece in and out until a good sharp focus is obtained on a screen of white cardboard placed on the floor nearly at right angles to the telescope tube.

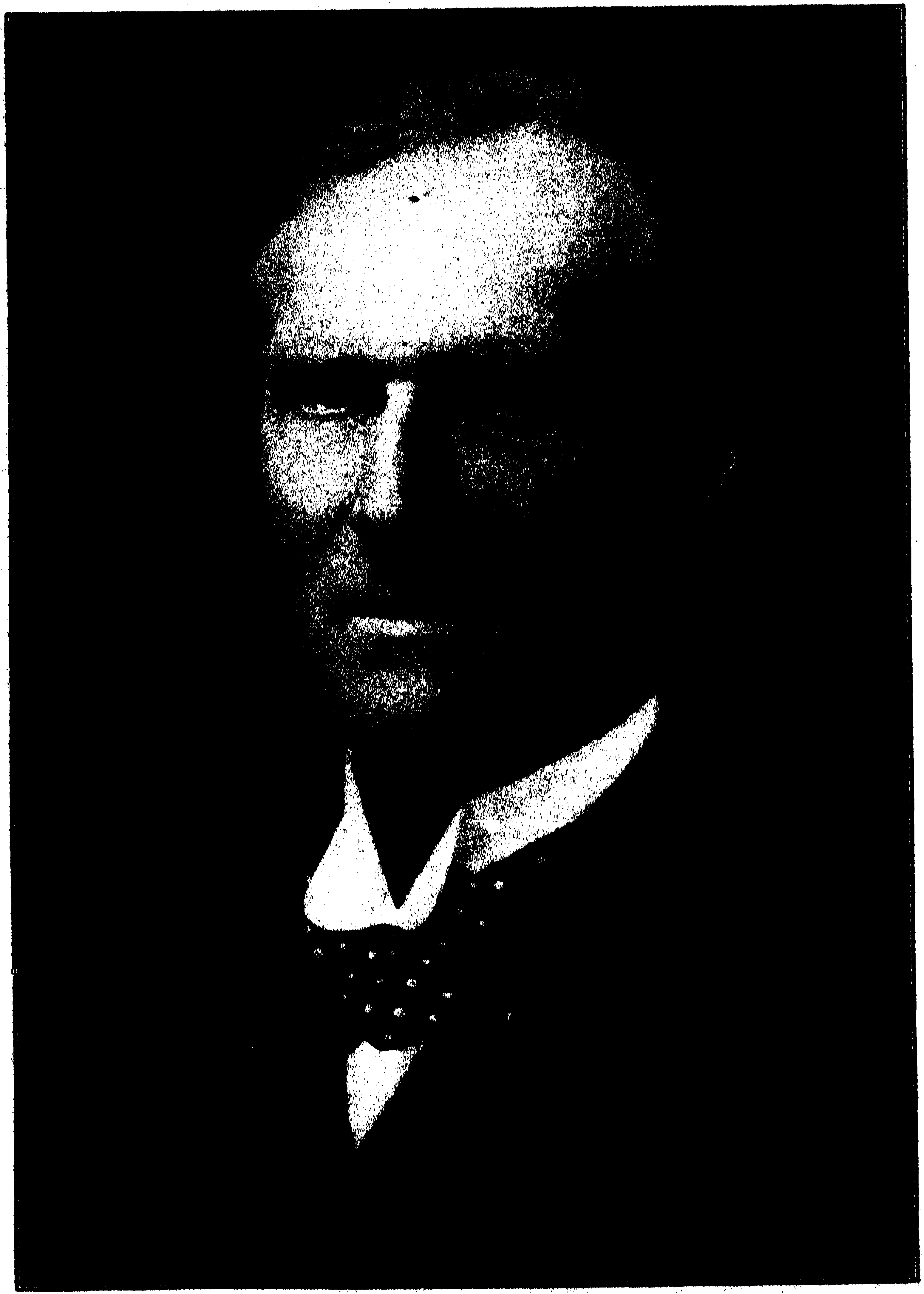
Upon this sun's disk sunspots are apt to appear at the present time. When watched from day to day they are seen to move from the east to the west side of the sun. Some spots last only a very short time. Others persist and reappear after having passed around the further side of the sun; some indeed make several rotations.

These spots are evidently blacker than the rest of the sun's disk. By the use of a delicate thermometer called a bolometer we have made measures of the heat from within these spots. They are so low in temperature that chemical compounds exist within them. We know this from the spectroscopic analysis of the light from the spots. Heat causes the particles or atoms of a gas to move hither and thither; the hotter the gas the more furious these movements, the atoms continually hitting each other. Over most of the sun the temperature is so high that if any two atoms come together to form a union or chemical compound such as might exist at temperatures we know here, they are instantly struck so fiercely by other atoms that the union is at once divorced. As just indicated, the cooler temperature of the spots permits a somewhat more extended union, long enough for us to note it.

The study of the formation of such compounds and the splitting up and remaking of even the atoms themselves at the high temperature of the sun (about 6,000° or more) now allows the astronomers to give the chemists a considerable amount of information relative to the formation of chemical compounds and the splitting up of what they once thought were indivisible elements. Despite the high temperature of the sun we are already providing terrestrial sources nearly as hot as that part of the sun which we see. Researches carried out at this observatory during the recent war show that the temperature of the arcs of some of the modern army searchlights approaches that of the sun.

The sunspots show that the sun rotates about its axis once in about twenty-six days. Something besides heat possibly comes from some of these spots, which are known to be whirls of electrified particles, which when it strikes the earth produces the Northern Lights, electrical and magnetic disturbances, interfering with telegraphic and radio transmission. There have been disturbed areas on the sun which have lasted through several rotations, so that the rotation of the sun could be very closely determined from the occurrence of magnetic storms, even though clouds continually kept us from seeing the sun itself.

Whence comes all this heat? That is a problem the greatest astronomers are now bent on proving. We know that each time a smashed or divorced atom picks up its parts or another mate the union is a very hot affair and at present the tendency is to blame or praise such atomic or sub-atomic processes for the heat we receive, sometimes too parsimoniously, sometimes too generously.



SIR ARTHUR KEITH

President of the British Association for the Advancement of Science for the meeting held at Leeds from August 31 to September 7. The subject of his address was Darwin's theory of man's descent as it stands to-day. Sir Arthur Keith, distinguished for his work in anatomy and physical anthropology, is conservator of the Museum and Hunterian professor of the Royal College of Surgeons, England.

THE PROGRESS OF SCIENCE

EDITED BY EDWIN E. SLOSSON

Director of Science Service

ADDRESSES BEFORE THE LEEDS MEETING OF THE BRITISH ASSOCIATION

YES! was the emphatic answer given by Professor Sir Arthur Keith, president of the British Association for the Advancement of Science, to the question contained in his presidential address opening the annual meeting at Leeds, England: "Was Darwin right when he said that man, under the action of biological forces which can be observed and measured, has been raised from a place amongst anthropoid apes to that which he now occupies?"

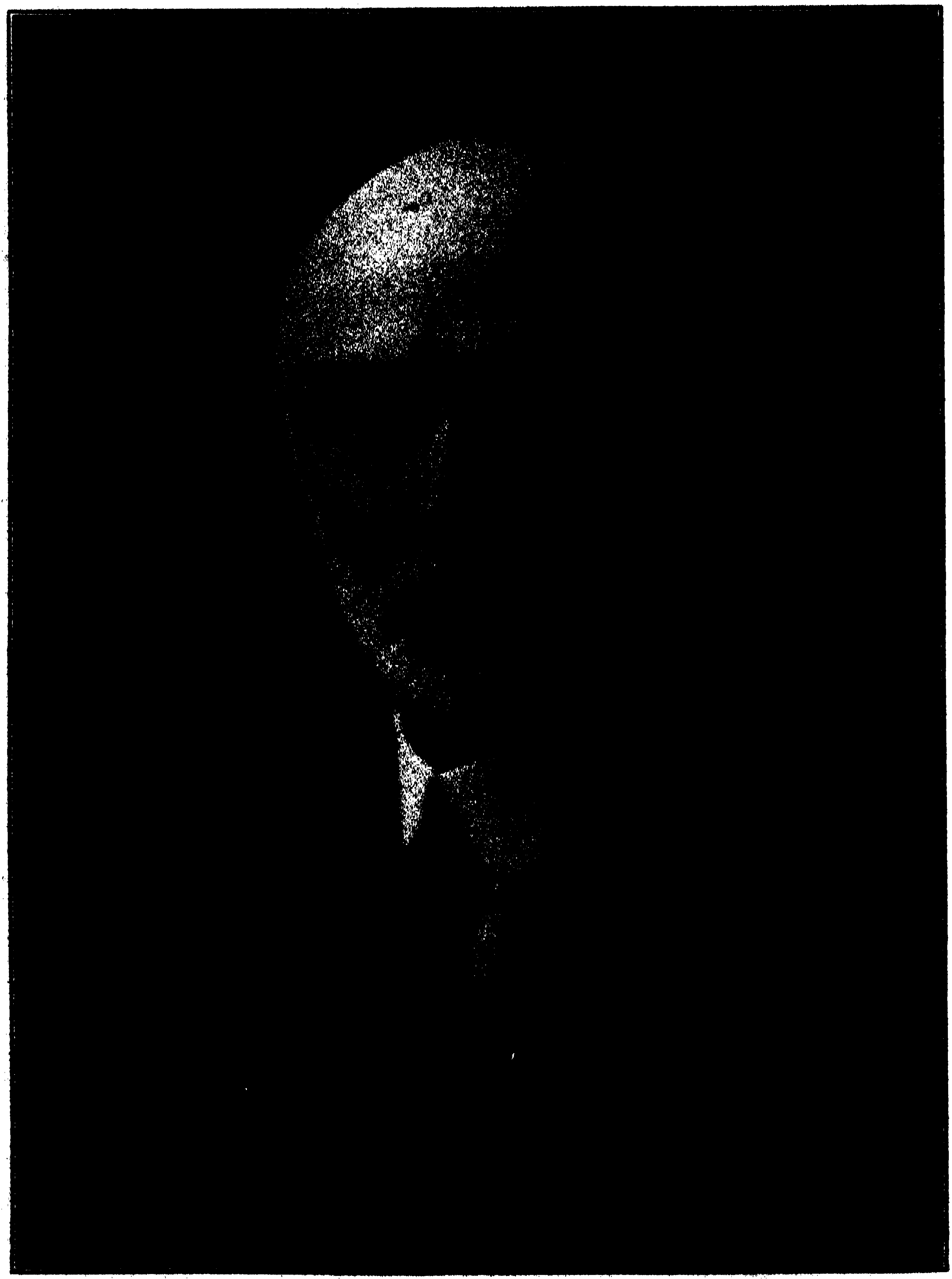
And this eminent London anthropologist and anatomist declared that, in rendering this verdict, he spoke not in the rôle of special pleader but as foreman of a jury that has been impanelled from men who have devoted a lifetime to weighing the evidence upon human evolution. "All the evidence now at our disposal," Professor Keith said, "supports the conclusion that man has arisen, as Lamarck and Darwin suspected, from an anthropoid ape not higher in the zoological scale than a chimpanzee, and that the date at which human and anthropoid lines of descent began to diverge lies near the beginning of the Miocene period. On our modest scale of reckoning, that gives man the respectable antiquity of about one million years."

Since Darwin made his revolutionary studies, Professor Keith explained, an enormous new body of evidence has poured in. It is now possible to fill in many pages which Darwin had perforce to leave blank; it has been necessary to alter details of the narrative, but "the fundamentals of Darwin's outline of man's history remain unshaken." Evolution is infinitely more complex than was suspected in Darwin's time. Professor Keith expressed this by saying: "To unravel man's pedigree, we have to thread our way, not along the links of a chain, but through the meshes of a complicated network."

As convincing proofs of man's anthropoid origin, Professor Keith cited the discovery that the blood of man and the great anthropoid apes give almost the same chemical reaction. Huxley's observation that there is no structure in the human brain that was not already present in that of the anthropoid has been confirmed by thousands of anatomists. The expansion of various parts of the anthropoid brain gave man his powers of feeling, understanding, acting, speaking and learning. Darwin's psychological observations, which convinced him that the differences between the mentality of man and ape are of degree and not of kind, have been verified and extended by modern psychologists.

Despite the advances made in tracing man's past, Professor Keith declared there is much that is not yet understood. Why, he asked, did the brain of man make such great progress while that of his cousin the gorilla has fallen so far behind? Why does inherited ability fall to one family and not to another? In the matter of brains, why has one race of mankind fared so much better than another? Such unexplained questions as these will be answered, Professor Keith believes, when such sources of knowledge as the new researches upon the endocrine glands and upon heredity are utilized.

ONE hundred million light-years. Such is the approximate maximum radius of the universe as estimated by Professor



HENRY PAUL TALBOT

FOR FORTY YEARS PROFESSOR OF CHEMISTRY IN THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY, DEAN OF THE FACULTY, IN WHOSE DEATH THE INSTITUTION LOSES ONE OF ITS MOST DISTINGUISHED LEADERS.

E. T. Whittaker, of Edinburgh University, in his presidential address before the Section on Mathematical and Physical Sciences. The light that is used as a yard-stick travels at the rate of 186,000 miles per second. Multiply the number of seconds in a year by this factor and then by a hundred million and the product will be the mileage of the universe's radius.

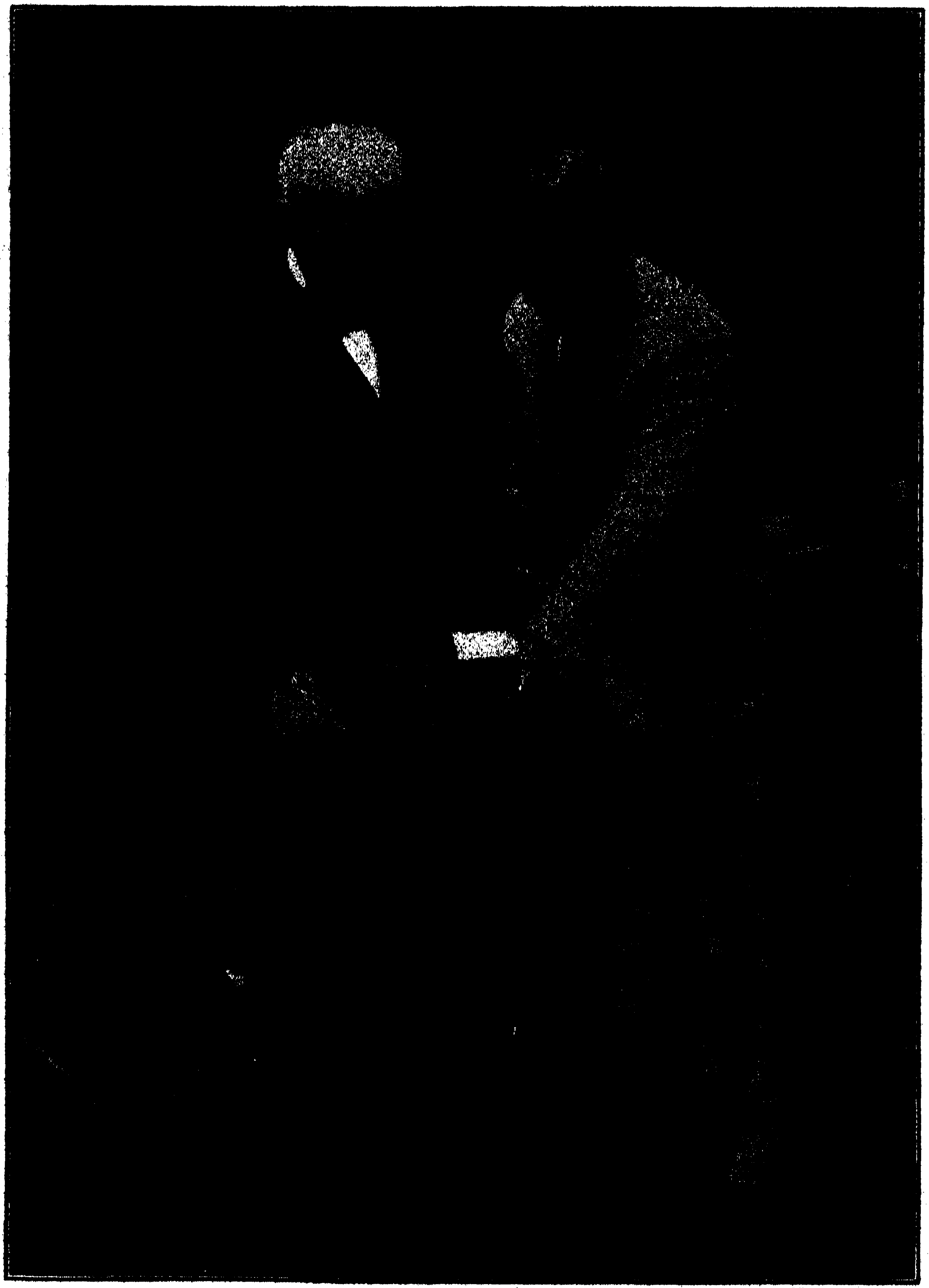
Light appears to an ordinary mortal to be traveling always in a straight line, but Einstein's theory of relativity, upon which Professor Whittaker's calculations are based, holds that the straightest light ray is curved in a third dimension due to the presence of matter. Most of the universe is a vast void of space even in a thickly populated region such as in our galaxy, so the curvature due to the total mass of matter is very slight and it takes a long time for light to make the circuit. Physicists explain that the universe is finite but boundless, very much as the surface of the earth has no end, but does have definite size. A ray of light starting out from a star because of this curvature of space is capable of traveling around the universe and reaching its point of origin from the opposite direction. By a strong magnetic field with laboratory apparatus it is possible to produce a curvature of space corresponding to a radius of only one hundred light-years, but this action is confined to a very limited area.

"THE proper study of mankind is man," and this holds for his inner physiology as well as for his mental and social activities. So claimed Dr. C. G. Douglas, of St. John's College, Oxford, speaking before the Section of Physiology. Experiments on animals are all very well for rough comparative results, Dr. Douglas said, but when we want to find out how the human machinery really works we have to make our observations on a man. This does not involve punching holes in him or sawing him up; it is the physiology of whole, normal, active human beings we are principally interested in, and this can be studied without pain or inconvenience to persons who volunteer for the work. Good beginnings have been made in the study of human physiology, especially in the field of oxygen requirement and other aspects of respiration. Food and its assimilation furnish an equally promising field, but one that has been less explored. Still other possibilities may be found in the chemistry of the blood and in the action of the nervous system.

THE Englishman of the future will be more high-browed from an anthropological standpoint than his ancestors, Professor F. G. Parsons, of the University of London, told the association in his presidential address before the Anthropological Section.

Reporting upon investigations into the constitution of the modern Englishman and his ancestors, Professor Parsons announced: "The head shape is showing unmistakable signs of an increase of its proportional height, with a decrease of its proportional length, and this increase of proportional height is greater than has been found in any of the stocks from which the modern Englishman is derived. It therefore can not be looked upon as a harking back to any ancestral form, but must be regarded as an evolutionary process, in harmony with the greatly changed conditions of life which have come about during the last century."

With reference to other characteristics, Professor Parsons said: "The Englishman of the future is, if present conditions persist, making for an average height of 5 ft. 9 in., and the women for one of 5 ft. 6 in. or 5 ft. 7 in. Our people have reached, and are stationary at, a stage in which some 66 per cent. have light eyes and some 34 per cent. dark. There are no signs whatever that the hair color has darkened during the last sixty years, though there are signs, which per-



—Wide World Photos

MR. THOMAS EDISON

WITH THE FIRST COPY OF THE PHONOGRAPH ON THE OCCASION OF THE CELEBRATION OF THE FIFTIETH ANNIVERSARY OF ITS INVENTION. GOVERNOR MOORE, OF NEW JERSEY, WHO IS SHOWN WITH MR. EDISON, PRESENTED TO HIM A PORTFOLIO OF FELICITATIONS.

haps need discounting, that the hair is lighter than it was sixty years ago."

LITTLE chance for the settlement of the great unknown Antarctic continent is held out by Dr. R. N. Rudmose Brown in his presidential address before the Section of Geography. "The Antarctic has no human problems comparable with those of the Arctic," he said. "It is true that whaling has recently invaded the Antarctic, with the vessels in the Ross Sea, not to mention the sub-Antarctic whaling in South Georgian and Falkland waters. But this can be little more than a passing phase. Already some species of whales show signs of depletion of numbers, and unless whaling is so rigorously shackled by regulations as to make it of little profit compared with risk it entails, the industry must kill itself in a few years' time. For the rest there is nothing of value in commerce in the Antarctic: certainly nothing that it can possibly pay to exploit. The stories of future Antarctic coal mines can be dismissed as a dream without any solid foundation. It is fortunate. And those of us who care for the wild waste spaces of the world are glad to think of the Antarctic as free from invasion by our modern civilization with its insistence on hurry and noise. We are glad to remember the lonely places of the world and their matchless beauty, content to know that to others they will bring the same fascination they did to us in years gone by."

With regard to the Arctic, Dr. Brown sees the possibility of scattered colonists of pastoral interests and fur farms here and there supplying high-priced Arctic furs in limited numbers. "The settlement of the Arctic must wait until the pressure of population or the world's resources is even greater than it is to-day," he said. "The remoter parts, those without rich tundra and the ice-covered seas and lands must remain deserts, visited only by roving hunters and occasional explorers. In short, I see a shrinking of the Arctic wildernesses, but never their disappearance. I can not take as glowing a view of Arctic settlement as Stefansson can, or visualize the same attraction to population which he forecasts, and I am skeptical of the value of Arctic lands as stations on the air routes of the future. But even if he has overstated his case, his long-sighted views have done something to dispel current misconceptions and reduce the area of polar wastes."

THE AGE OF CHEMISTRY

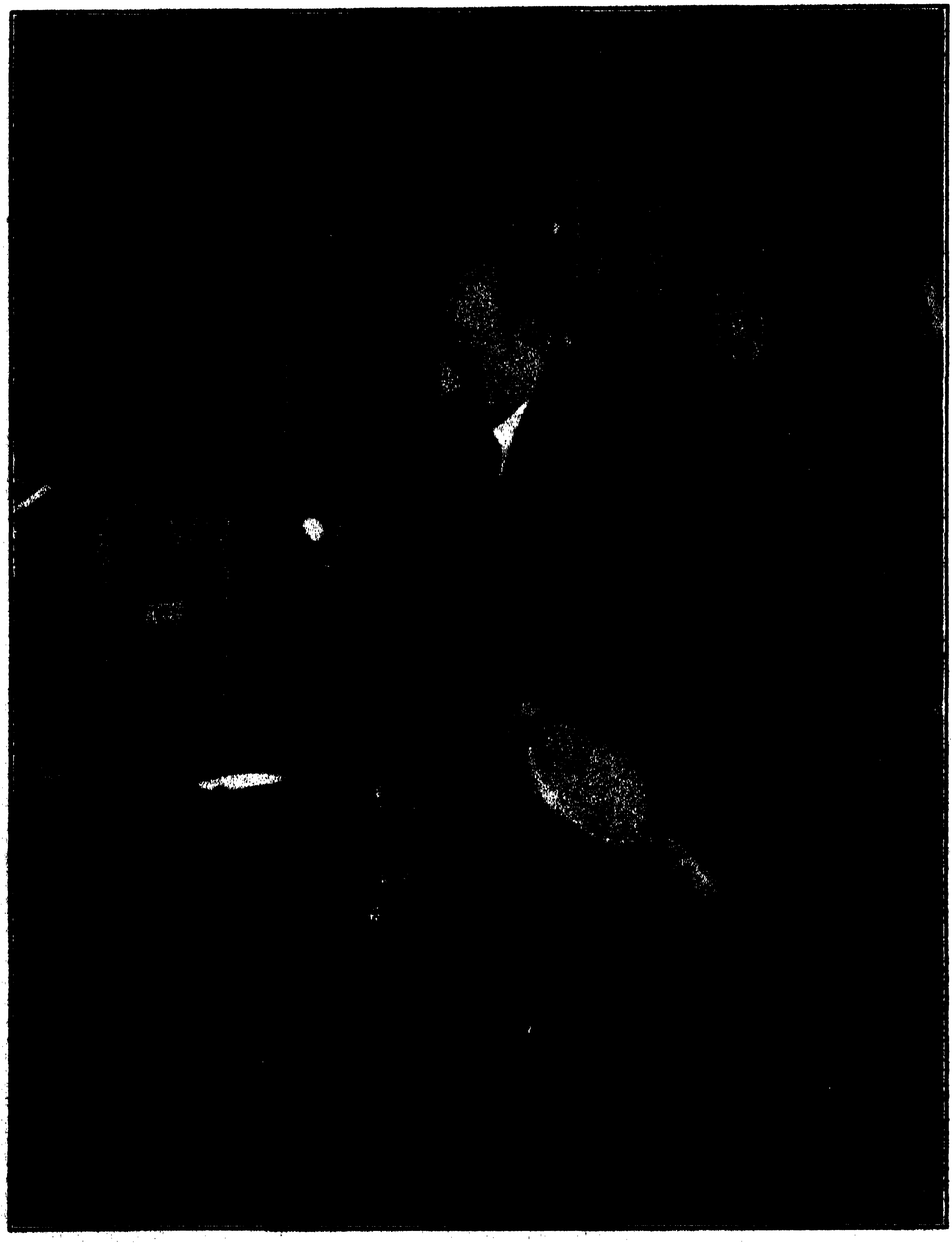
PREVIOUS stages of man's history have been known as the Age of Stone, the Age of Bronze, the Age of Iron and so on. The present is preeminently the Age of Chemistry. This was the thesis of the presidential address delivered before the American Chemical Society at its principal general session, by Dr. George D. Rosengarten, of Philadelphia, head of the society during the present year.

Even in the past, chemistry played a leading part in man's progress, Dr. Rosengarten declared, though man has not always been conscious of its importance. The change from the Age of Bronze to the Age of Iron, 3,000 years ago, was largely a chemical change.

The task of the present and the immediate future, he told his hearers, is the full mastering of the basic principles of chemical science.

"An important problem and one requiring our immediate and undivided attention is so-called 'pure chemistry.' I should rather like to call it 'science of chemistry' in contradistinction to the practical application of chemistry which would be more correctly designated as the 'art of chemistry.'

"Pure science is the protoplasm of applied science. It is the brick and mortar of our skyscraping buildings of industry



THE PHOTOELECTRIC CELL

In series with ammeter and electrolytic cell for the measurement of daylight, as developed by Dr. Lewis R. Koller, in the Research Laboratory of the General Electric Company.

and commerce. Our civilization of which we are so proud, the comforts of life we are enjoying are wholly built on discoveries emanating from the search for scientific truths, from the pursuit of science for the sake of the science itself. As Secretary Hoover has very tersely put it: 'It is in the soil of pure science that are found the origins of all of our modern industries and commerce.'

"The relationship between the science of chemistry and its varied and multitudinous applications is quite apparent to the chemist, but for our lay guests let me cite one or two of the thousands of examples. About one hundred and twenty years ago, Sir Humphry Davy in his pursuit of scientific knowledge for the sake of knowledge discovered a method of separating the 'refractory' metals potassium and sodium from their combinations. Based on this fundamental discovery, Hall, an American, and Heroult, a Frenchman, prepared the metal aluminum. But for the availability of this metal, aviation would still have been a Midsummer Night's Dream. This metal has also added immensely to family happiness. Aluminum kitchen utensils are easy to wash and keep clean, making less work in the household, and thus stabilizing domestic felicity."

THE PHOTOELECTRIC CELL AND ITS APPLICATION TO THE MEASUREMENT OF DAYLIGHT

THE phenomena of photoelectricity have been known to scientists for many years, but it has been only comparatively recently that they have been put to any practical use.

In brief the phenomena are as follows: When light falls upon a metal, the light causes electrons (or negative particles of electricity) to be emitted from the surface of the metal. If there is a positively-charged object nearby, then the electrons will be attracted toward it, their flow constituting an electric current.

Metals differ greatly in this property, some emitting electrons much more readily than others under the influence of light. The alkali metals are particularly photo-sensitive. The nature of the light is also an important factor as photosensitive materials are more sensitive to blue than to red light. That is to say, more electrons are emitted for a given quantity of blue than of red light.

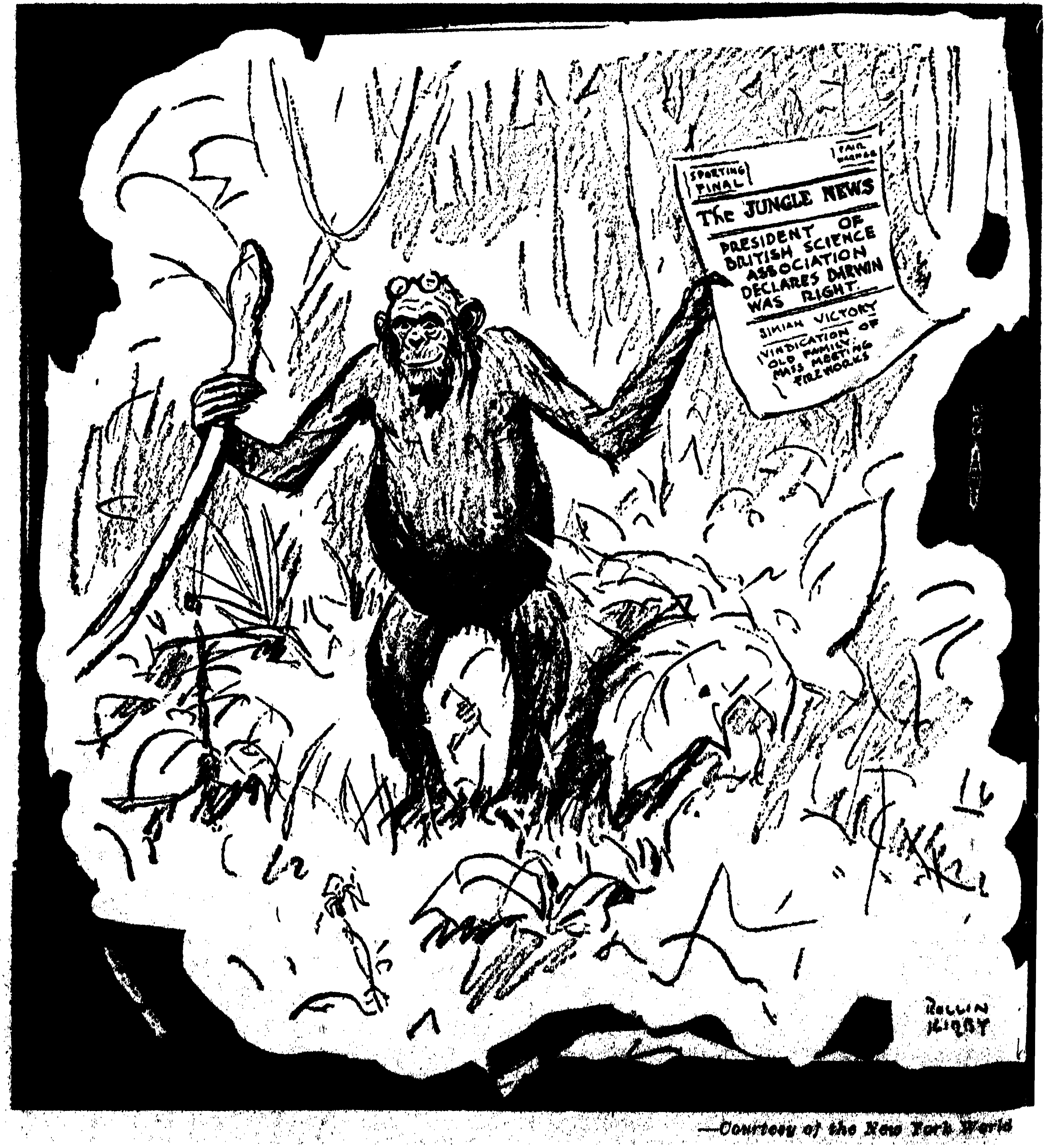
The photoelectric cell which makes use of these phenomena is commonly in the form of a glass bulb. The inner wall of the bulb is coated with a thin layer of the light-sensitive material, a circular opening being left for the light to pass through. In the center of the bulb, and insulated from the walls, is the positive electrode or anode. The bulb is exhausted to a high degree of vacuum.

The anode is connected to the positive end of a battery and the metal coating (or cathode) to the negative terminal. Since these two are insulated from each other, no current flows through the cell if it is kept in the dark. If, however, light is permitted to fall upon the circular opening, or window, electrons will be given off by the cathode and will be drawn over to the anode. The current thus produced is the photoelectric current. The particular usefulness of the photoelectric cell lies in the fact that the magnitude of this current is directly proportional to the intensity of the light falling upon the window. Thus an electric current can be used as a measure of light intensity, and any changes in the light intensity are instantaneously translated into changes in current. Changes too small to be noticed by the human eye can be measured accurately by means of the photoelectric cell.

One very interesting application of the photoelectric cell is in the study of daylight, its intensity and its variations. The cell used for this purpose is a large, spherical bulb, seven inches in diameter and silvered on the inside. Deposited on the silver is an extremely thin layer of the light-sensitive metal. This layer is very active photoelectrically. The anode is connected as already described to the positive terminal of a battery, and the cathode to the negative. When the cell is exposed to daylight, a current flows through this circuit and any changes in the intensity of the daylight are faithfully followed by the current. The current is made to operate a recording meter which records the values of the current on a continuously moving strip of paper, which gives a permanent record of the daylight hours.

Studies of daylight are of interest in connection with illumination of buildings, street and sign lighting, growth of plants and many human activities. The photoelectric cell also finds many applications in industry in phenomena involving light.

"TELL IT IN TENNESSEE"


SPORTING FINAL
FAIR WARMER
The JUNGLE NEWS
PRESIDENT OF BRITISH SCIENCE ASSOCIATION DECLARES DARWIN WAS RIGHT.
SIMIAN VICTORY
VINDICATION OF OLD FAMILY
MASS MEETING
FIREWORKS
ROLLIN KIRBY

—*Courtesy of the New York World*

THE SCIENTIFIC MONTHLY

NOVEMBER, 1927

MYSTERY MONUMENTS OF THE MARIANAS

By Lieutenant-Commander P. J. SEARLES
NAVY YARD, BOSTON, MASS.

THOUSANDS of miles from civilization, hidden in tangled jungle growths, seldom described and photographed, as have been the pyramids of the Mayas, the ruins of Angkor Wat or the monstrosities of Easter Island, for hundreds perhaps thousands of years, have lain concealed the mystery monuments of the Marianas. Surpassing Stonehenge in extent, with single stones larger than any in the pyramids of Egypt, these Lat'te or "Casas de los Antiguos," as they were known to the Spanish, are the relics of a race whose origin is lost in the dim mists of antiquity and whose history and characteristics had even been forgotten over four hundred years ago. What are they, why were they erected, and by whom? These are puzzles still to be solved.

The Marianas, or Ladrones, as they were formerly called, form a group of Pacific islands, roughly in Longitude 145 East and Latitude 12 to 18 North. Guam, the largest and most important, is an American naval station, while the others, Saipan, Rota, Tinian, Pagan, Agrigan, etc., were acquired by the Japanese following the World War. They are all typical tropical islands, with flora and fauna such as is widely found in the Pacific, and peopled by thousands of amiable, intelligent, handsome Chamorros, gently indolent under the southern sun. Thanks to American and Japanese influence, they have been provided with many modern comforts, electric lights, sanitary water supply, ice and cold storage, radio and cable service, medical attention, etc., without losing the quaintness and picturesqueness of the primitive.

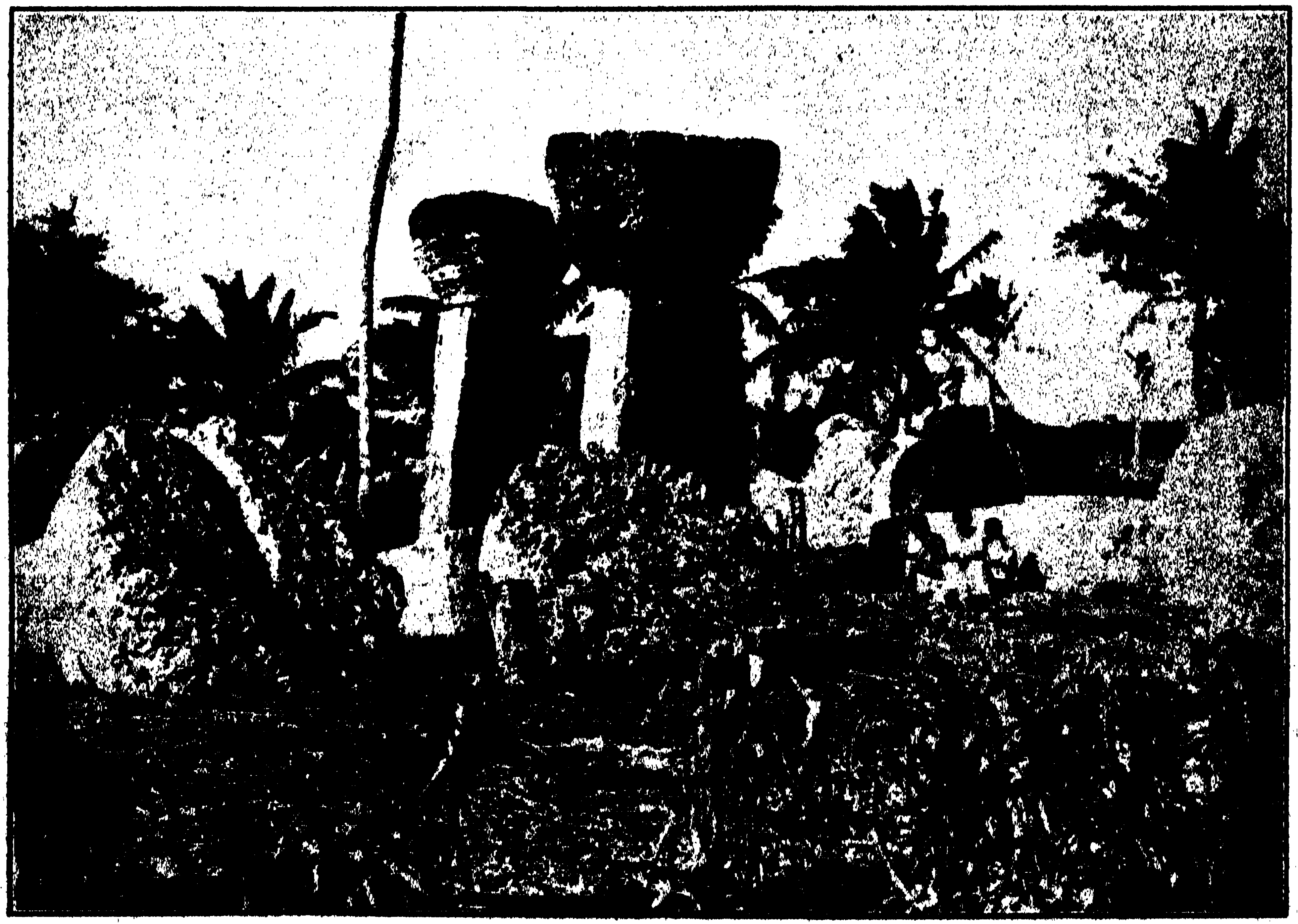
Dotting the islands here and there are found those magnificent structures, the Lat'te, erected unknown centuries ago by a lost race whose name even is forgotten. Massive and imposing even when partially laid low by the hand of time working through earthquakes and typhoons, hid in the shadowy depths of the jungles, they convey an impression of high intelligence and skill on the part of their builders. Baffling to the scientist as well as to the layman, they represent an ancient epoch as mythical as Atlantis. What are they?

A Lat'te is composed primarily of upright monoliths called "halege," surmounted by hemispherical capitals called "tasa." The upright stones are usually placed in two parellel rows of from four to six stones in each row, the long axis of the Lat'te always being parallel with the line of the sea shore or a river bed. In Guam are found several different detailed forms. The uprights are sometimes slab-like, sometimes cut square; in fact, many shapes are extant. The capitals also vary in shape and size. Lat'te range from small rude structures constructed of natural boulders capped with coral heads, to massive stone columns, square in shape, fifteen or more feet in height and six feet in diameter, headed with enormous blocks of stone.

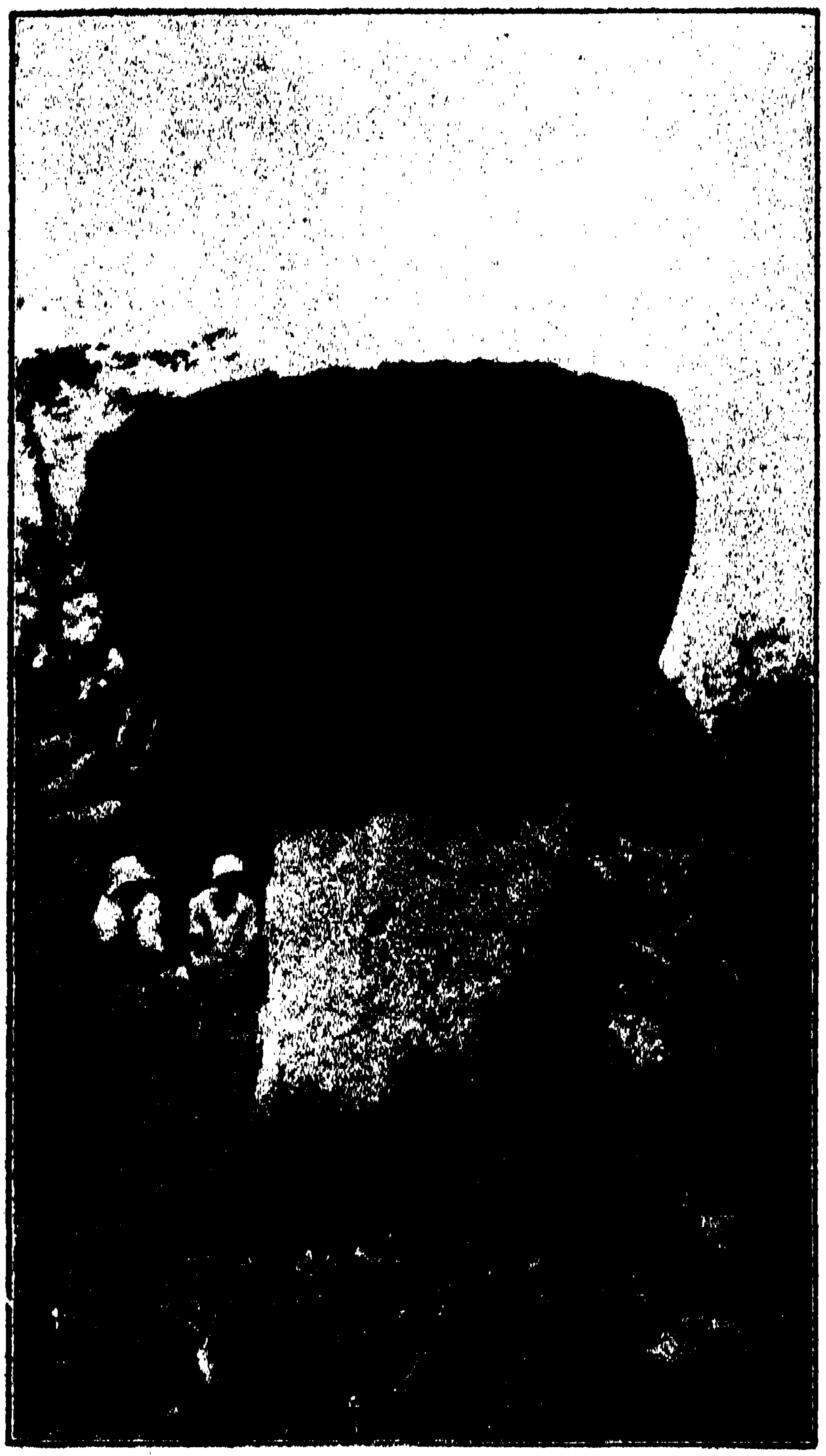
The Island of Tinian presents two of these largest of monuments carved by prehistoric man, part of the "House of Taga." The only standing survivors of ten original monoliths, these two shafts still rear their lofty heads on the southwestern side of the island, very near the beach. Three others are completely shattered as if by earthquake, two have lost their capitals, and three have fallen but still retain the "tasa" intact. They are all shaped like truncated pyramids, capped by hemispherical stones. The pillars are eighteen feet in circumference at the base and fifteen feet at the top. They are twelve feet high and support capitals five feet high and six feet in diameter. Each monolith weighs about thirty tons. The two parallel rows originally stood seven feet apart and form a ground plan about fifty-five feet long by eleven feet wide. They are cut from a rough metamorphosed coral known in the Marianas as "cascajo."

Don Felipe de la Corte de Calderon, Spanish governor of the Marianas from 1855 to 1866, in various manuscript reports to the Crown (not published), tells of the Lat'te.

> It should also be noticed that not only Guam, but Rota, Tinian, and Saipan also possess ruins of houses of an architecture which tends to demonstrate the existence of a people gifted with certain ideas which showed them to be above the stage of the mere savage. All these ruins consist of pyramids finished at the top with semi-spherical, carved stones, the semisphere in some instances being biult of small stones cemented together.
>
> In all the islands, at places formerly inhabited, are found certain monuments, which the natives call "latde" (sic), or "Houses of the Old People." They consist invariably of a



"THE HOUSE OF TAGA"
Island of Tinian.



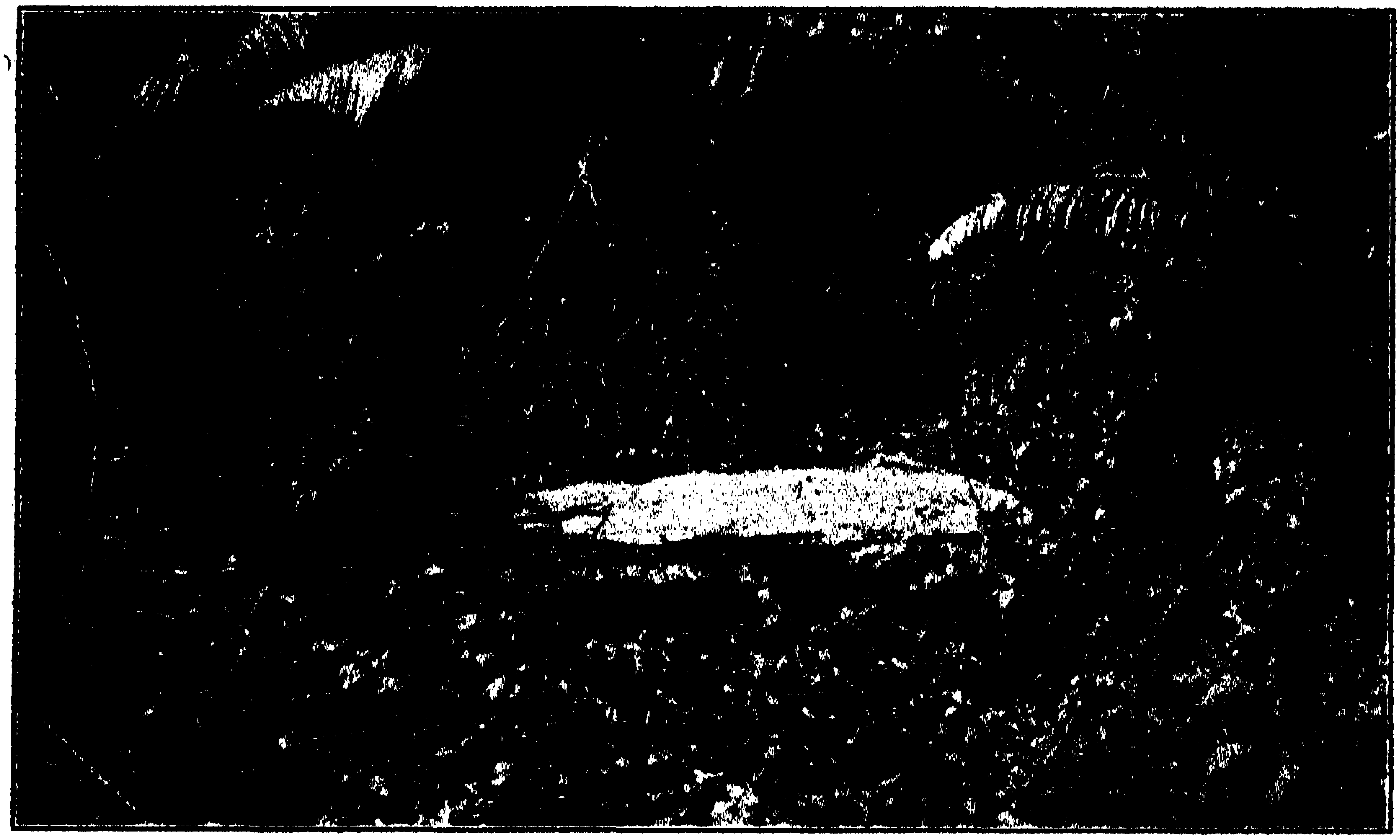
ONE OF THE SMALLER LAT'TE OF GUAM
SHOWING THE "HALEGE" AND THE "TASA."

double row of rough stone pyramids or truncated cones, supporting stone hemispheres, flat side up. These pyramids, similar in shape to the stone pillars called "Guarda Cantones," which are often placed along the edges of royal highways in Spain, stand in two rows, like the pillars of a house; and even though we have no exact data on the subject, this position together with their native name makes us believe that formerly they served as supports for stringers on which rested rafters that reached to the ground; but if this is correct, the house must have been very low. In early descriptions of the islands it is said that the natives buried their dead in the houses and even today the people have a superstitious fear of digging up or working the ground between these rows of stones. . . .

In Guam, Rota, and Saipan, the latde pillars consist of only two rough hewn stones, one cone shaped and the other a half sphere placed on top of it, both of them together not being higher than five feet from the ground; while in Tinian close to the Deputy Governor's house stands a group of these pillars, called "House of Taga"—a chieftain famous in local history—which is composed of twelve truncated pyramids four or five feet wide at the base and fifteen feet high, their squared tops measuring about two feet to a side. On them rest hemispheres from six to seven feet in diameter.

These pillars, crowned with their hemispherical caps and standing in two files, distant from each other about four varas from center to center, constitute a monument worthy of special attention, not so much for its size as because it resembles nothing to be seen elsewhere outside of the Marianas; moreover, it is not unique, but represents a type repeated over and over again in the other islands of the group. If we knew more about these latde we might determine the true origin of these natives of whom it may be confidently asserted that they are not the descendants of primitive savages. This is proved not only by the labor and skill required to dress the stones, but also by their unvarying

A LAT'TE COLUMN ON GUAM
ABOUT SIX FEET IN HEIGHT. THE WOMAN IS ONE OF THE FINE TYPE OF CHAMORRO.



THE JUNGLE REMAINS OF AN ANCIENT LAT’TE

> pyramidal and hemispherical character. It seems strange that the history of the first missionaries makes no mention of them, since one would think such pillars could not fail to attract attention when discovered among the thatched huts of naked Indians.
>
> Tradition has it that Taga buried his daughter on top of one of the pillars and covered her corpse with rice flour; when I visited this monument in 1855, wishing to confirm the story handed down by word of mouth, I had a ladder brought and climbed to the top of the pillar mentioned in the story and actually found a cavity full of earth and overgrown with shrubs whose trunks were two or three inches thick. After it had been cleaned out by my orders, I found a piece of a human lower jaw and two small bones, evidently finger phalanges. The grave cavity in the top of the hemisphere measured about five feet long by one and a half feet wide and deep, the corners being rounded.

Calderon is not altogether accurate, especially as regards the size of the Lat’te and about their not being mentioned by early missionaries. Gaspar and Grijalva described a boat house as being supported on strong stone pillars and sheltering four of the largest canoes. Richard Walter, chaplain of the “Centurian,” one of the ships of Lord George Anson, who visited the Marianas in 1742, speaking of the Lat’te, says they are “in a style of grandeur passing anything which has been seen in the dwellings of the more eastern islands of the South Seas.” In one of the narratives of Legazpi’s expedition, it is said that some houses were supported on stone pillars and used as sleeping apartments, whereas cooking buildings, etc., were built on the ground. Legazpi mentions “arsenals” supported on stone posts. Reasons will be advanced later why it is not believed at present that the monuments were supports for houses or other buildings, but had an entirely different purpose.

> Of the cause of their destruction we know nothing [says Arago, draftsman to Freycinet’s expedition which landed at Tinian in 1819], for what credit can be given to a story like the following that the people are fond of relating: Toumoulou Taga was the principal chief of the island. He reigned peaceably and no one thought of disputing his authority. On a sudden one of his relations called T’jocnanai raised the standard of revolt, and his first act of insubordination was to build a house similar to that of his chief. Two parties were formed; they fought; the house of the revolter was sacked; and from this quarrel which became general

arose a war that, while it depopulated the island, overturned its primitive buildings.

This tale is not now in circulation and certainly is apocryphal, for Arago's narrative in general is not entirely reliable. The chronicler continues:

> The ruins best preserved are those to the west of the anchorage. The building there was composed of twelve pillars; of which seven only remain standing, the others lie at their feet; and what appears singular is, that the half sphere by which they were crowned has not been separated in their fall. Those found by the side of it (and the remains of which are more decayed, situated near the well, denominated the "well of the ancients") formed an edifice more than four hundred paces in length. The roots that still bind these old fragments, and the shrubs that crown their summits, present an interesting view.
>
> Their proximity; their form; their material; the stone being composed of sand, consolidated by cement; that half-sphere surmounting a baseless pillar, erected on the arena; their position, and the distance that separated these different masses, without any lighter fragments occurring between them, induce me to think differently of the object of the building from the present inhabitants, who regard it as a royal residence. The space between the pillars is scarcely greater than the ground they occupy. What purpose could these massive tops answer? Who was the sovereign who inhabited the colonnade which certainly formed only a single edifice; the more I perambulate these ruins, and compare them with the genius of the present race of islanders, the more I am convinced that they are the remains of some public temple dedicated to religion.
>
> To what God, to what spirit, to what genius was this temple consecrated? For it was certainly a temple, this vast monument more than a thousand feet in circumference.
>
> Much has been made of the pillars on the island of Tinian, shaped like the rest in the form of a truncated pyramid and capped by hemispherical stones, wrote William E. Safford, but, in all probability, they are nothing more than the remains of large houses which served the same purposes as the "arsenals" described in the narratives of the Legazpi expedition.

Anson's chronicler says:

> The equal height of the pillars and the shape of the capitals explain that they were designed for lodging a floor or platform and for preventing the ascent of rats and other noxious vermin. . . . Tinian swarmed with rats who were bold and familiar.

While the "House of Taga" is the most known of the Lat'te or "casas de los antiguos," there were rediscovered in 1924 on the island of Rota by Mr. Hans G. Hornbostel, of the Bishop Museum of Honolulu, remains of far greater structures. The principal edifice consists of twenty-five circular columns, four feet in diameter, and from four to sixteen feet high, forming a colonnade about eight hundred feet across.

The most impressive feature of the Lat'te is their enormous size and extent. In extent the one just mentioned is larger than Stonehenge, and the monoliths of fifty or more tons are heavier than the largest blocks of the Egyptian pyramids. But why were the Lat'te erected and by whom? As Arago says: "But what people erected above the earth these imposing masses, more than thirty feet high, well carved, regular without sculpture which fixes or which gives a clue, even, of the probable epoch of their mysterious foundation. What has become of the architects?"

Recent investigations indicate that the Lat'te are not remains of ancient dwellings, but that they are monumental religious structures, marking sites of ceremonies, cannibal feasts and burial. Many bones, pottery and other artifacts have been unearthed from the Lat'te sites. In Saipan, for example, a complete skeleton was found about two feet below the surface of the ground, lying on its back with its feet toward the sea. When the Japanese in Saipan excavated for buildings and for a railroad they unearthed relics of what must have been a vast ancient population. Bones, weapons, pottery, ornaments, have been found in Guam in such style and quantities as would preclude the Lat'te having been part of dwellings. Natives to-day frequently refuse to touch bones or articles taken from Lat'te, as they are supposed to belong to "Tautau mona" or "people who came before," and consequently have evil powers.

In Guam the Lat'te sites can be considered as being divided, roughly, into three areas or groups. There is first the area of burial, which extends perhaps twenty feet from the Lat'te toward the sea or running water. Then there is an area devoted either to warriors slain in battle or possibly to prisoner victims of cannibal feasts, as shown by the skeletons having signs of considerable mutilation, such as broken skulls, missing legs or arms, spear heads in the skeleton. The third general area extends several hundred feet from the Lat'te toward the water, but not inland, and contains the remains of ornaments, pottery, weapons, stone implements, and is sometimes marked by a large stone mortar.

From the position of the skeletons it is thought that water bore a mystical or symbolic relation to life and death in the minds of the ancients. The feet almost always point toward the sea or running water and the head inland. Perhaps water was a symbol of birth and if, as seems possible, the ancients believed in a life after earth, the feet of the dead were placed toward water so that upon arising the newborn would be oriented toward the direction of new life. Some such relation there must have been or ceremonial burials would not have been conducted with such precision. Seldom is the position of the skeleton varied, and where this is the case, the skeletons are found carelessly interred outside a Lat'te as if to indicate lack of regard for the deceased, possibly because he or she were a criminal, cowardly enemy or some other such undesirable creature. Burials never took place on the landward side of Lat'te. Males were buried deeper than females, and children at a shallower depth.

The remains indicate that the builders and users of the monuments were cannibals. When illustrious dead were to be buried, ceremonial feasts were held at which, in addition to the regular foods, human flesh was consumed, the remains being deposited in the grave with the other articles, possibly to support and aid the dead in the journey to the next world. The victims of the cannibal feasts may have been unfortunate prisoners of war, but more probably were selected from the tribe itself, as the remains are more frequently of children than of adults. Perhaps in connection with the ceremonies the sun was worshipped, as stone dishes have been found with the design of the sun cut in.

How the Lat'te were built is unknown. Tools, chipped and polished from a basaltic rock, were the only implements the primitive people had, yet they formed blocks of fifty tons or more. The cultural level of the Egyptians was vastly superior to that of the ancient Polynesians, the Egyptian workmen knowing the use of bronze cutters set with diamonds and corundum, yet their pyramidal stones were not so large. Mr. Hornbostel has advanced the interesting and plausible theory that the stones were shaped by the alternate use of fire and water, the fire to heat and the water to crack, the process continuing until a huge monolith was fashioned from the rocky earth, later to be more carefully carved by the stone implements. By whatever means secured and erected, the Lat'te remain magnificent monuments to an ancient race, comparable, in size, skill and industry required, to the remains at Stonehenge, Easter Island or the Maya cities.

Who built the Lat'te and when? This is a mystery which may never be solved. It was almost certainly not the Chamorros found in the Marianas by the Spanish discoverers and settlers. When the Spanish first arrived, the Lat'te were already partly in ruins, and the natives disclaimed all knowledge of the builders, except that they were "the people who came before." Cannibalism was unknown and forgotten by the sixteenth century, yet remains of cannibal feasts are found in the Lat'te. Perhaps they are relics of ancestors of the Chamorros, ancestors long dead and forgotten. Perhaps they were erected by a race antedating the Chamorros and which has disappeared in the mists of the past. Nothing corresponding to the Lat'te is found in Polynesia, but archeologists hope that in Micronesia and Melanesia further study may give a clue. Were the Lat'te only part of dwellings (though this hardly seems possible), were they temples to the sun or were they religious structures dedicated to ancestral worship? Have they a relation to any Asiatic monuments or to the astounding and unique figures of Easter Island? These questions still remain to be answered. But there in the Marianas the Lat'te stand or lie fallen in the tangled jungles, hidden by the dense growth of vegetation, far from the ways of man; monuments to a people of genius, lost in antiquity, who perhaps with weird rites sacrificed to the blazing tropical sun at a time when Rome ruled the world and Christ taught in Jerusalem.

THE ELEPHANT HEADS IN THE WALDECK MANUSCRIPTS

By J. ERIC THOMPSON

FIELD DIRECTOR OF THE BRITISH MUSEUM EXPEDITION IN BRITISH HONDURAS

THE casual discovery of a water-color and a drawing in an unpublished manuscript nearly a hundred years old may revolutionize our concepts of American history before the arrival of Columbus.

Some time ago the late Edward A. Ayer, well-known Chicago benefactor and trustee of Field Museum, Chicago, purchased the unpublished manuscripts, water-colors and drawings of the well-known nineteenth century explorer, Baron Waldeck. These documents he subsequently presented to the Newberry Library, of Chicago, where they now form part of the Edward E. Ayer collection.

The writer, while engaged on research work at the library, coming upon them, realized their importance as a possible source for the reconstruction of Maya history. Here were three perfectly good elephants' heads (Figs. 1, 2). If they were indeed trustworthy copies of the originals, how did it come about that the Mayas could reproduce so faithfully the features of the elephant? The true elephant, though once it roamed the plains of America, has been extinct in the New World for scores of centuries. It certainly ceased to exist long before man first crossed into America. The mammoth, too, was almost certainly extinct in America before the advent of man, yet if Baron Waldeck is to be trusted, the Mayas had a pretty shrewd idea of what an elephant's head looked like and could carve as good a representation of an elephant's head as any modern artist set to sculpture an elephant from memory or some crude drawing.

Baron Waldeck was one of the earliest explorers to make a detailed study of any group of Maya ruins. As early as 1832 he was at Palenque, measuring the ruins and copying the inscriptions and sculptured figures. He was engaged on this work for two years, and during such a long stay he had, needless to say, the opportunity to become thoroughly acquainted with every corner of the ruins.

Palenque, which in Spanish means "hitching post," is situated in the modern state of Chiapas in South Mexico. The climate is tropical and the whole country is covered with dense forest. The city itself is one of the finest ruins in the whole Maya area. Large temples set upon lofty pyramids abound and everywhere are found exquisite carved stones and stucco reliefs. The art of Palenque is unsurpassed by any other Maya city; indeed, it would be no idle boast to assert that Palenque art is superior to anything Egypt or Babylon ever produced. One of the finest buildings at Palenque is known as the "Palace," or Temple "C," and it was in a subterranean room beneath this building that Baron Waldeck discovered these memorable sculptures. On the wall was the elephant's head depicted full face (Fig. 2). The shaded part marks the part that Waldeck himself restored, as the original had in the course of centuries suffered considerable deterioration. The center of the drawing shows the elephant's head with mutilated trunk in air revealing the typical small diamond-shaped mouth of the elephant. Above and to each side are perched two grotesque birds. The restoration made by Waldeck is based on similar birds found elsewhere at Palenque. Long necklaces, probably of jade, hang from their necks, terminating in pendant jade masks. The treatment of the feathers is very beautiful. Note how the tail feathers sweep round beneath the geometric design.

The water-color (Fig. 1) depicts four stucco strips found by Waldeck amidst the rubbish on the floor of the same chamber. Waldeck surmises that in all probability they once formed part of the border of a stucco panel, possibly the panel showing the elephant full-face. The first strip shows two elephants' heads peeping out from amid the foliage of a vine. Here the representation is still more close to the original elephant. The tip of the trunk is neatly curled up and the tusks are very prominent. Note the large ears. Around each head is placed a band with a large jewel resting on the forehead. The leaves of the vines are very naturalistic. The second strip shows practically the same motif, but here, instead of elephants' heads, human heads are depicted. Possibly they represent Itzamna the sky god, who is usually shown with a large Roman nose.

The third strip shows two animals, which, though highly conventionalized, possibly represent tapirs. At all events the animal is obviously totally distinct from the elephant. In contrast to the huge cabbage-leaf ears of the elephant, this animal has sharp pointed ears. The treatment of the long nose is quite distinct, as too are the general features.

The fourth strip has as its motif what are apparently eggs.

If one could place full confidence in Waldeck as a trustworthy artist, there could be no reasonable doubt that the original did indeed represent elephants. Waldeck, however, who was in many ways more of an artist than an archeologist, was not strongly blessed with the gift of accuracy. A comparison of some of his drawings with photographs and the accurate drawings of A. P. Mandsley, reveal, on occasions, marked discrepancies. Waldeck, though accurate on general outlines, often displays a tendency to slur over minor details.

Furthermore, Waldeck held preconceived theories on the Asiatic origin of the Maya civilization, and any one looking for proofs to substantiate his theory seldom has any difficulty in finding them. Waldeck may, therefore, have "read into" the original figures elephants' heads which actually never existed. However, the boldness of the outline of the first strip would seem to point to the fact that he was copying from a clean and undeteriorated original. Unfortunately, the originals have in the course of the subsequent ninety odd years disappeared, and any hope of checking up on Waldeck's accuracy has thereby been dissipated.

For many years the belief has been generally held by the majority of American anthropologists that the civilization of America developed on American soil quite independently of outside influence. These scientists hold that such cultural traits as agriculture, pottery, the use of stone in architecture, metals, sun worship and other religious concepts were evolved here and were not borrowed from the Old World. On the other hand, there has recently grown up in Europe, especially in England, a school of "diffusionists."

The English diffusionists, whose chief exponents are Professor Elliot Smith, the famous anatomist, and Dr. W. J. Perry, lecturers in anthropology at London University, believe that a cultural trait is only invented once in the history of the world. These diffusionists hold that agriculture, pottery making, the use of stone in architecture, pyramidal structures, preservation of the dead, the use of metals, forms of social organiza-

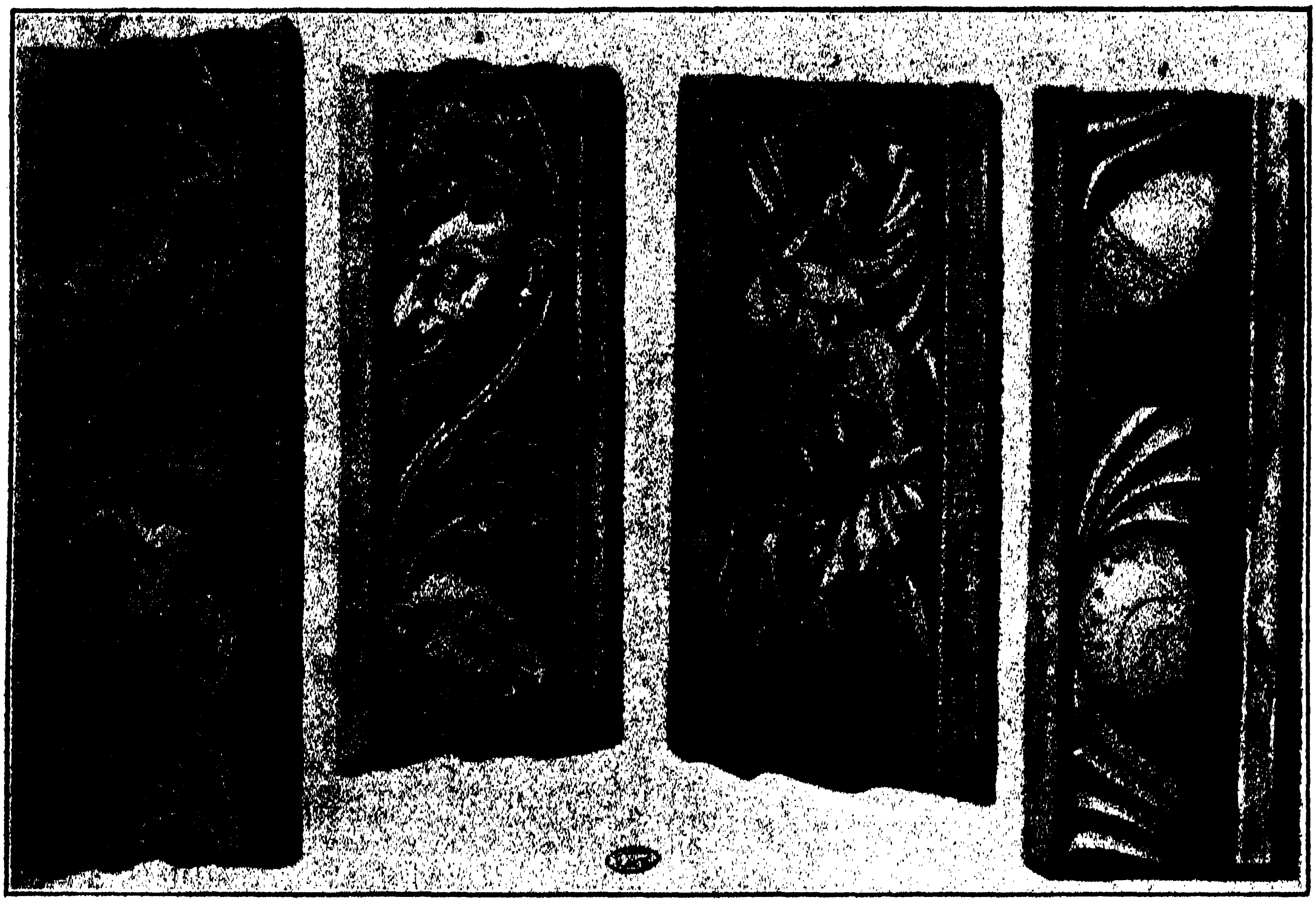


FIG. 1. FOUR STUCCO STRIPS WITH ELEPHANTS' HEADS

tion and a score of other cultural traits were introduced into America by immigrants from across the Pacific. The home of these original travelers was Egypt, and, led by princes of the royal Egyptian blood, who claimed descent from the sun, they sallied forth from Egypt in search of gold, pearls and precious stones. Wherever they penetrated they found the aborigines living in a primitive Stone Age state. They settled among the aborigines, where as rulers they were worshipped as Children of the Sun and introduced their civilization and culture. Subsequently cut off from the original sources of their culture these outposts of civilization gradually degenerated, a process which was still working when the Spaniards reached the New World.

This theory has not found general acceptance in America, where the majority of anthropologists still hold to what might be described as the "Monroe Doctrine of Anthropology," or hands off America, home-grown American civilization for the Americans.

Elliot Smith some time ago attempted to show that certain Maya sculptures were intended to represent elephants, but his deductions were not generally accepted. Had he proved his point a serious blow would have been dealt to the Monroe doctrinaires, for had these sculptures been accepted as representations of elephants, the question at once arose, how did the Mayas ever become acquainted with the form of the elephant?

The diffusionists, of course, reply to this that the immigrant from across the Pacific introduced the worship of the elephant from Asia.

The Americanists, however, refused to recognize that these early sculptures represented elephant heads, but claimed instead that they represented macaws' or tapirs' heads.

Even should it be admitted that elephants' heads were portrayed on these

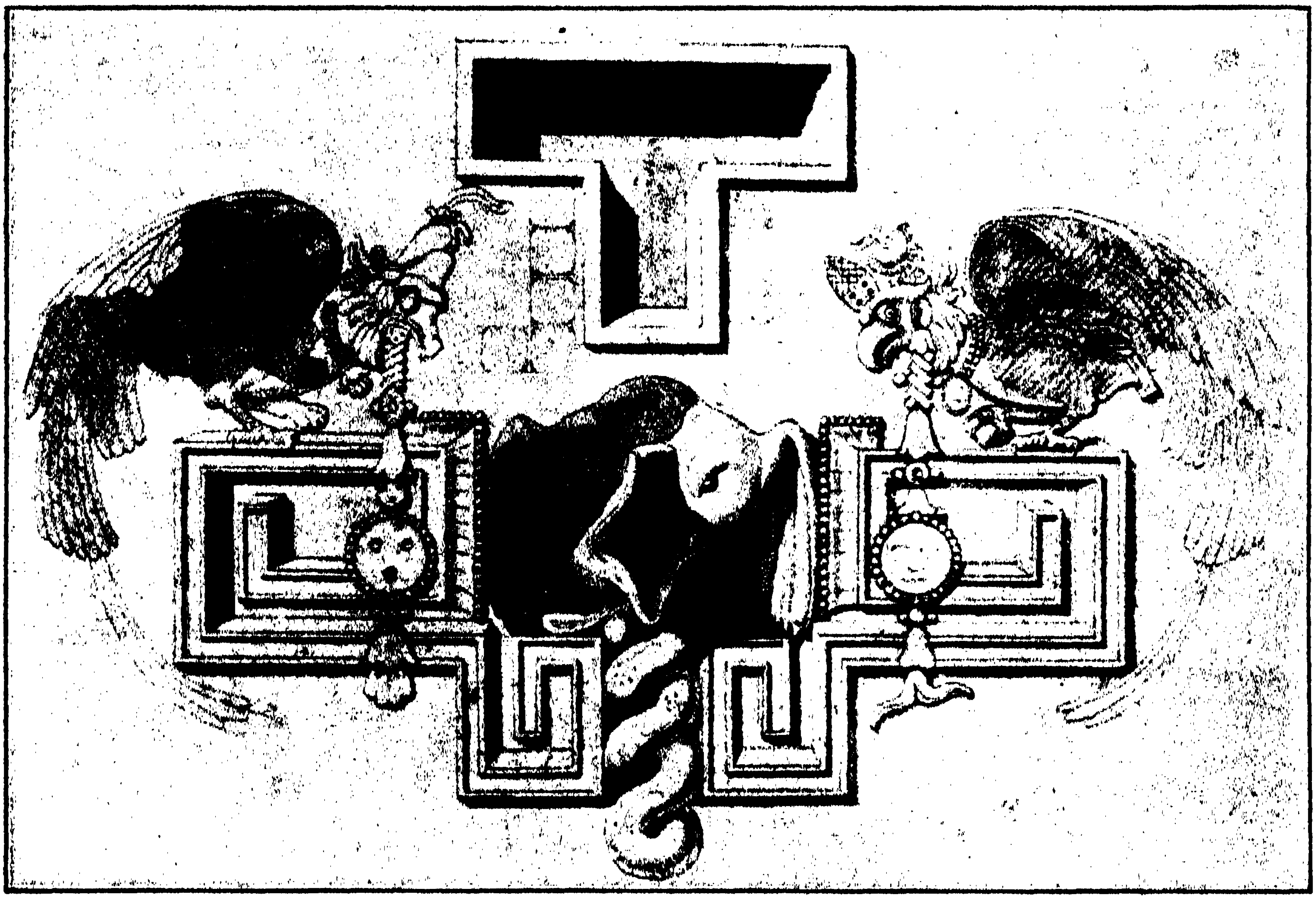


FIG. 2. ELEPHANT'S HEAD

Maya carvings, the diffusionist arguments would be as far from proved as ever. The attitude that American civilization was never affected to any appreciable extent by Asiatic influences would have to be abandoned, but there is a great difference between conceding this point and admitting that the whole of American civilization was of Asiatic origin.

Agriculture in the New World shows evidence of considerable antiquity. Many centuries must have been required to develop domesticated maize from its probable Mexican progenitor, the Mexican fodder grass. Furthermore, the agricultural products contributed by the New World are distinct from those originated in the Old World.

But the elephant motif appears in Maya art only about one thousand to two thousand years ago, the latter figure being in all probability too early. Thus agriculture existed in America long before the elephant motif, if indeed it is of Asiatic origin, was introduced.

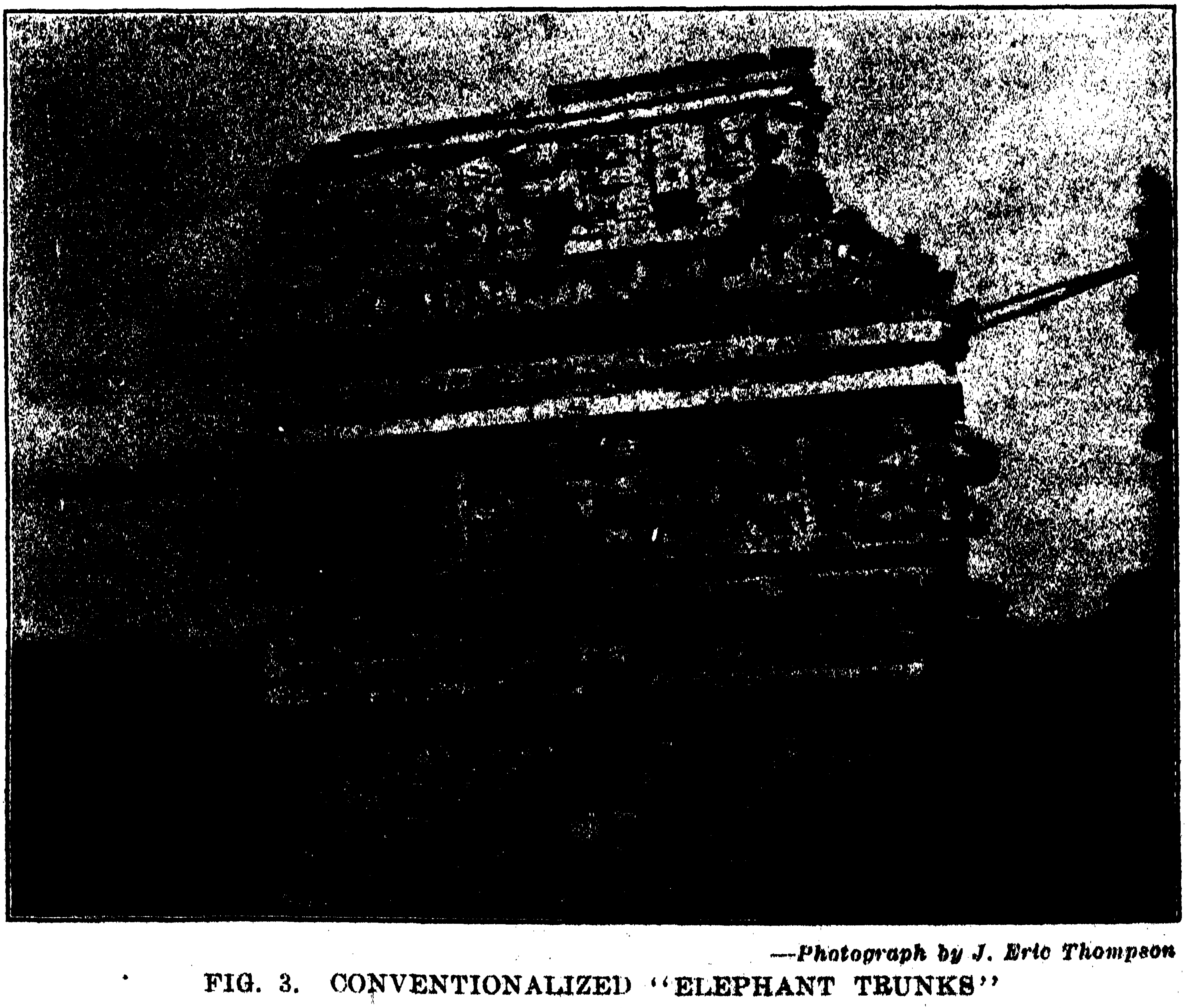
In the Pueblo area of our southwest, thanks to the work of Earl H. Morris and Dr. A. V. Kidder, we are able to trace history down from the earliest primitive non-pottery-using basket-makers to modern times. Following on a period when no pottery was used, but only baskets, appears a period when the ancient Pueblo peoples made primitive pottery by daubing clay on their baskets. This is not definite proof of the invention of pottery in this area, but it is at least highly suggestive. Possibly pottery was invented quite accidentally in this area through a mud-covered basket having been close to a fire; the clay baked and the first pot had been made.

The diffusionists' belief that the arrival of the Children of the Sun synchronized with a sudden development of a high culture, followed by a period of gradual degeneration, can also be shown to be ill-founded as far as the New World is concerned.

The earliest culture of which we have any sure knowledge is the so-called Archaic. The Archaic peoples covered the whole area from Mexico to the northern third of South America. Their civilization, though relatively advanced, shows many signs of crudity and lack of sophistication. The Archaics in Mexico and Central America wove quite good textiles, built adobe pyramids and made fairly good pottery bowls.

The Archaic culture was probably flourishing in the Valley of Mexico about 1,000 B. C. We are able roughly to date this culture, thanks to an accident, unlucky for the Archaics, but extremely lucky for modern archeologists. The Valley of Mexico was in the past a center of considerable volcanic activity. The lava flows from one eruption buried beneath its flow a considerable part of the valley. There are geological grounds for believing that this eruption occurred at the latest about 1,000 B. C. To-day the archeologists can dig below this lava crust and find the remains of archaic cemeteries and pyramids which were overwhelmed just as Pompeii was overwhelmed by the eruption of Vesuvius.

The Archaic civilization formed the basis on which the Maya and Toltec civilizations rested. Dr. Manuel Gamio during the past year laid bare many of the links that connect the Archaic culture with the Maya. He discovered new archeological sites in Guatemala that show the gradual evolution of the Archaic into the Maya. Almost step



—*Photograph by J. Eric Thompson*

FIG. 3. CONVENTIONALIZED "ELEPHANT TRUNKS"

ON ONE OF THE MOST BEAUTIFUL REMNANTS OF MAYA ARCHITECTURE AT CHICHEN-ITZA.

—*Photograph by J. Eric Thompson*

FIG. 4. TYPICAL MAYA OF TO-DAY

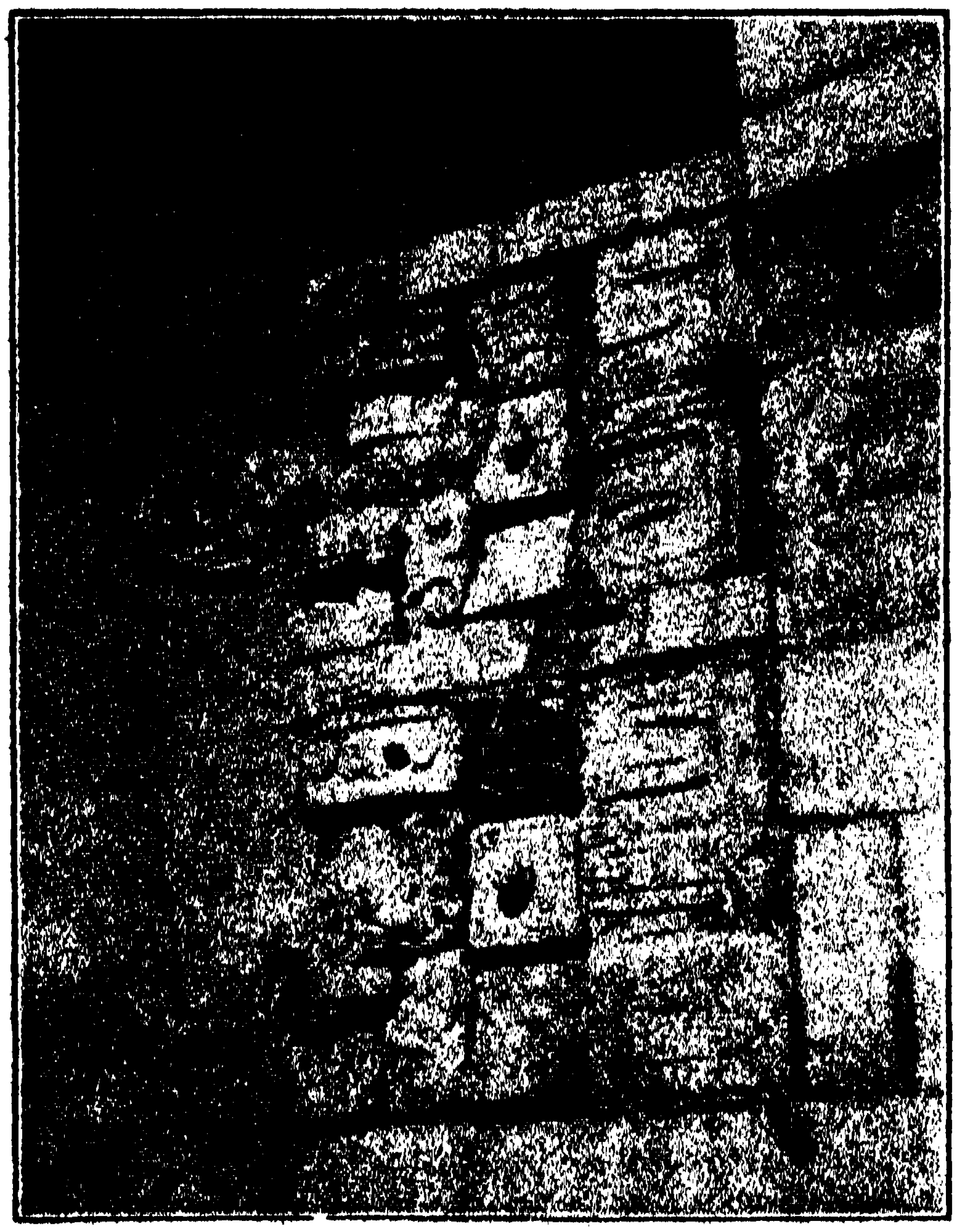
Descendant of the builders of the Old Maya Empire. Ethnologists claim to see a resemblance in this pure-blooded Maya to Hindus; an interesting comparison with Hindu native might be made.

by step we can now watch the crude, primitive Archaic blossom forth into the classical beauty of the Old Empire Maya. So we see that instead of a sudden hot-house-like burst of culture followed by degeneration, the development has been slow and gradual but ever upward.

According to the diffusionist theory copper and bronze implements should be abundant in the early stages of American culture, but as time progressed and degeneration set in they should become scarcer and scarcer. Again the facts contradict this.

The early Archaics and the Maya of the Old Empire were apparently unacquainted with metal. It was not until late in New Empire times that metals came into use. Similarly in Peru, bronze and copper can be shown to be very rare in early times, but common just before the arrival of Pizarro and the Spaniards.

Dr. A. L. Kroeber, in the course of excavation in southern Peru for the Field Museum of Chicago, opened a very large number of Proto-Nazca graves. The Proto-Nazca is the earliest civilization known in South America. Out of the enormous collection of objects made from these cemeteries by Dr. Kroeber only some three or four objects are of



—*Photograph by J. Eric Thompson*

FIG. 5. DECORATIVE ELEMENTS ON A MAYA BUILDING AT CHICHEN-ITZA

Which supporters of the elephant theory maintain are masks representing degenerate elephant heads with protruding trunks. The large teeth in the mouth of the sculptured mask is regarded as evidence of the "elephant original" in contradistinction to the tapir or macaw theory.

metal, and these are all very small trinkets.

The Incas, however, who arose to power in Peru only some two hundred odd years before the Spanish conquest were abundantly supplied with bronze, copper, gold and silver. Inca collections, as well as collections from their contemporaneous neighbors, the Calchaqui of Northwestern Argentine, comprise enormous quantities of metal.

Architecture, too, shows evident traces of a gradual development. The Maya buildings of the comparatively late New Empire far surpass anything of which the Old Empire was capable.

Thus we see that in plastic art, the use of metals and architecture, the archeology of the New World upholds the tale of gradual development.

The position then seems to be this: The civilizations of the New World developed independently of outside assistance from the Old World beyond the fundamentals of life which the first invaders from Siberia brought with them. It will be generally agreed that the early immigrants brought with them on their long trip from Siberia across the Bering Straits into America via Alaska such fundamentals as the making of fire, the use of skins as clothing and the chipping of stone to make tools. Probably, too, the spear and the spear-thrower, the making of baskets and possibly even the bow and arrow should be added to this list.

Then, if the elephants are to be depended upon, long after civilization in the New World had gotten under way, influences that crossed the Pacific from Asia profoundly affected it.

Culturally, the effect would not have been great, but in the realm of religion the Asiatic influences may have been considerable.

In art, too, the effect may have been widely felt, for in every community except possibly the most sophisticated, art and religion are bound together by the most intimate ties.

As in so many thorny and problematical questions, each side will probably have to retreat from its uncompromising position sooner or later. The eventual solution of aboriginal American history will be found to lie between these two extremist viewpoints. What is required of archeologists to-day is less theorizing and more actual work. The Maya area is still to all intents and purposes a virgin field. The surface has as yet been barely scratched. Expeditions galore have traversed the Maya area, returning with reports of hardships and new sites discovered. It is not thus that history is reconstructed. With the exception of the work of the Carnegie Institution at Chichen Itza no attempt has ever been made to excavate systematically a Maya site. Systematic excavation is the only method of gathering the ends together. By painstaking but not spectacular methods is the past made to yield its secrets.

At present archeologists are too prone to fight with their tongues, forgetting that the weapon of the archeologist is his spade. Ten years' systematic excavation should go far to solve these problems on which to-day so much verbal energy is spent.

THE GOLD COAST

By CHARLES H. KNOWLES

DIRECTOR OF AGRICULTURE, GOLD COAST[1]

THE Gold Coast is one of the British colonies in west Africa. It is situated on the northern shore of the Gulf of Guinea and lies about five degrees north of the Equator. It occupies roughly a rectangular area covering over 91,000 square miles, and has a population of two and one fourth million natives and two thousand non-natives. The native population consists of many races and tribes speaking several different languages.

The climate is hot; in the forest it is humid, but it is much drier in the open country, comprising a narrow coastal belt in the eastern part and covering most of the country from about two hundred miles inland. For a tropical country the rainfall is not high. In the eastern coastal belt it is only about twenty inches a year; it reaches fifty to seventy-five inches in the forest and about forty-five inches in the open country. Most of the rain falls in the wet season, which extends from June to September. About the end of December a dry hot wind blows in from the Sahara. This is known as Harmattan and it is frequently laden with fine dust which is extremely trying. At the beginning and end of the rainy season tornadoes are

MR. KNOWLES ABOUT TO SET OUT ON AN EXPEDITION FOR PLANTING OIL PALMS common, and sometimes do much damage by blowing down trees.

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[1] One of the Smithsonian series of radio talks arranged by Mr. Austin H. Clark and given from Station WRC, Washington.

This part of the coast can not be called a health resort. In the old days malaria was so common that the country came to be known as "The White Man's Grave." However so much more is now known as to how to ward off this and other fevers and conditions in other ways have improved to such an extent that the name can no longer be applied without great injustice to the country.

The Gold Coast derives its rather pleasant-sounding name from the fact that gold is widely diffused there. Gold was the first reason for European trade, and it has regularly been exported since the discovery of this part of the coast in the fifteenth century. The wealth of the country proved very attractive to members of the various seafaring nations and considerable rivalry was thereby engendered. At first trading was done from the ships, but the European traders soon commenced to establish themselves on shore, the establishments taking the form of forts which were protected by cannon, both to ward off raids by the people of the country as well as to protect the interests of the builders from the unwelcome attentions of rival nations.

The history of the various forts would fill many volumes, some of them having changed hands many times, falling sometimes to the natives but more frequently passing from one European nation to another by conquest. The last to change hands in the Gold Coast was by purchase. Many of the forts are in a state of excellent preservation. Christiansborg Castle, near Accrá, the chief town, is the residence of the governor, while others are used as government offices.

The first administration of the country was by a company of merchants which was dissolved in 1821, and its possessions were then vested in the Crown, at first combined with other settlements on the coast, but constituted as a separate colony in 1874.

The early days of settlement were marked by various small disturbances, and after the people along the actual coast had become friendly and welcomed a measure of protection and settled administration, the more inland tribes, particularly the Ashantis, remained antagonistic until the beginning of the present century.

The whole country is now quite settled and the people can devote their whole energy to improving their well-being without the distractions incidental to protecting themselves against their neighbors or trying to redress fancied wrongs.

The Gold Coast is what is known in the British Empire as a Crown Colony. The government consists of a governor appointed by the Crown. He is advised by an executive council of officials, while a legislative council consisting of officials, representatives of the industries and of the people, makes the laws and controls finances, all subject to the general control of the Secretary of State for the Colonies. The people are governed through their chiefs. The various activities of government are carried out by a series of departments, the officers of which form the civil service.

Great headway has been made in sanitating the towns, while education and improved communications have had a material effect in improving the health of the inhabitants. Hospitals are established at all the principal government stations and medical offices are stationed at many other centers. At Accrá, the Gold Coast Hospital is one of the finest examples of a modern up-to-date hospital to be found in any tropical country. Attached to it is the Medical Research Institute and a training center for nurses and dispensers. It accommodates some hundreds of patients. Separate hospitals are established for Europeans, and recently a maternity and child-welfare hospital has been established at Accrá under a woman doctor.

There is a keen demand for education. There are over 35,000 children in regular attendance at recognized schools. The latest development has been the establishment of the Prince of Wales College and School near Accrá at a cost of some three million dollars. It will provide instruction from the kindergarten upwards to university standard and will set the standard for the whole colony. The whole system at this institution rests on adapting education to native mentality, tradition and needs. It is a residential school and consists of substantial buildings containing quarters for students, classrooms, laboratories and the quarters for the staff. Recreation and playgrounds are provided and there is a large farm where agriculture can be taught. A staff of European and African teachers of the highest qualifications has been got together and part of the school is now working.

Up to the present the only way of reaching the steamers, which run direct from the coast to Europe, the United States and Canada, from the shore or *vice versa* has been by means of surf boats and lighters. Surf boats are sturdily built craft specially adapted to ride the surf which beats on the whole length of the coast line and which can be very heavy at times and at certain places. Indeed goods are sometimes lost, while occasionally passengers have had an exciting bath in the ocean. Each boat is propelled by about ten men—nearly always from the Liberian coast and known as Kroo boys—who adopt what seems to be an extremely uncomfortable and insecure perch on the gunwale and use a short paddle with a blade ending in three points based on the shape of the foot of a crocodile. These Kroo boys are exceedingly expert and apparently untiring boatmen.

A large harbor, however, is now nearing completion which will accommodate the largest steamers trading on the coast and providing full facilities for the rapid and safe handling of cargo. The cost will be about fifteen million dollars.

There are nearly five hundred miles of railway running from the ports of Accrá and Sekondi and meeting at Kumasi, the capital of Ashanti. One hundred miles of the railway is a branch running into the triangular area enclosed by the Accrá and Sekondi lines and the coast.

The railways are fed by about 4,700 miles of motorable roads, constituting the best and most developed system in British West Africa. Nearly three fourths of this mileage has been constructed in the last six years, and improvements of existing roads and extensions are being steadily carried out. Some of the roads are constructed by the chiefs and their people on their own initiative, showing their great desire to have the country developed.

People engaged in trade have been quick to see the advantages of motor transport and thousands of lorries or trucks are now on the roads. Indeed, as in many other countries, the railways are feeling the effects seriously of this competition.

As has been mentioned, gold attracted attention from the earliest times. Mining was entirely in the hands of the natives until the latter part of the nineteenth century. In 1879 a European company commenced working and from then there has been a rapid growth of the industry. Some of the mining ventures have been unfortunate, being heavily handicapped in the transport of heavy machinery through forest country entirely without roads. Much machinery is still to be seen abandoned in the forest without ever having reached its destination. Many mines, however, are working successfully and in 1925 the value of gold exported was over four million dollars. Diamonds were found a few years ago and are now being mined. The export increased from $1,800 in 1920 to $900,000 in 1925. There are important manganese and bauxite deposits. The former were discovered during the war. Four thousand tons were exported in 1916, the quantity increasing to 340,000 tons in 1925. The mines fortunately are on the railway not far from Sekondi.

The people are chiefly agriculturists. They grow their own food and in former times used to extract rubber from certain vines and trees and prepare oil and kernels from the fruit of the oil palm for export purposes. At the present time, however, the only industry of any importance is the cultivation of cocoa.

The establishment of this industry had a certain amount of chance about it. One of the few islands near this part of the coast—the Portuguese island of São Thomé—has had cocoa cultivations for many years. Laborers were frequently obtained from the mainland. In 1871 one of these men, returning to his home in the Gold Coast, took with him a few cocoa pods, the seeds of which he planted in his garden. Trees soon developed and he gave away or otherwise distributed the pods, explaining what a lot of money was made out of them in São Thomé. It was soon seen that the trees thrived and a considerable demand for seed arose, so much so that as much as five dollars was paid for a single pod. Large quantities were then imported and planting became general.

The Department of Agriculture established demonstration plots where seed could be obtained, where information was available as to planting and cultivation of the trees, and where demonstrations as to methods of treating the plants and working up the crop were given. Officers of the department were sent through the country to teach farmers who could not visit the plots. The spread of the cultivation of cocoa, however, was so rapid that the efforts of the officers of the department could not keep pace and much ill-advised planting took place. However, in spite of this the soil and climate of most of the forest areas were so thoroughly suited to the requirements of the plant that the majority of the farms thrived even under a minimum amount of attention. The exports increased amazingly until now the Gold Coast is not only the largest cocoa producing country in the world, but it produces one half of the entire world's supply.

The first export was less than one hundred pounds in 1884. The exports rose to over 50,000 tons in 1913 and reached a record in 1926 with 235,000 tons. It will interest you to know that your country is our largest customer for cocoa. There are two very striking points in regard to the industry. The first is the rapid growth and the second is that it is entirely in the hands of peasant proprietors or small farmers, who plant as a rule a few acres each, while most of them are illiterate. It is here that the cocoa industry of the Gold Coast differs entirely from the industries of most tropical countries where planting is an organized business employing foreign capital and under the direction of highly trained agricultural experts; such, for example, as the sugar industry of Hawaii, the rubber industry of Ceylon and Malay and Java, the tea industry of Ceylon and the cocoa industry in many countries.

The people were quick to see that the crop offered much better prospects with far less labor than those they previously worked in such as palm oil making and rubber extraction, and they were ready to act on advice as to the methods which for a permanent crop differed so very much from those found satisfactory in the shifting cultivations of their annual crops.

The cocoa industry of the Gold Coast,

worth some fifty million dollars, shows what the individual farmers of a small country can do by their collective effort, entirely unaided by the use of what we should call capital, and it is an industry of which the country may justly be proud. The people have sometimes been credited with much success in avoiding the more strenuous forms of labor, but I think the cocoa industry alone proves that they can, and do, apply themselves to steady work which they know is to their advantage.

Being so dependent on one crop is equivalent to having all one's eggs in one basket. A watchful eye, however, is being kept on the basket. A law has recently been introduced requiring attention to be given to trees attacked by certain diseases. A special staff is employed for the purpose, while the general staff of the department, consisting of mycologists, entomologists, chemists and botanists as well as numerous trained tropical agriculturists, devote the major part of their time to matters connected with the industry.

Other industries which are being encouraged by the government are coconuts for copra, limes for lime juice, grape fruit, rice, cotton and sisal hemp.

The cultivation of Para rubber is successfully established and is carried on on European plantations and also by the natives. An effort is being made to revive the palm oil industry by the use of improved methods, while an effort is made to improve the quality of food crops.

At all towns facilities are provided for recreation and exercise by the establishment of cricket and football grounds, tennis courts, golf links and polo grounds.

Much sport is to be had. Several species of birds provide excellent sport and excellent food. Antelope is to be found in all parts from the small Dyka to the large harnessed antelope and in places larger species.

Elephants occur in several parts of the colony and the working up of ivory is a regular industry here and there. Leopard are found in the forest, and smaller members of the cat tribe are common. Lion and hyena are frequent in the more inland areas.

Pythons of large size exist and a variety of snakes—harmless and otherwise, while crocodiles of two species abound in the large rivers.

Those of us who are privileged to travel regularly through the country and who have a liking for natural history find much of interest, while an encounter with some members of the fauna can be anything but dull.

TROPICAL CLIMATOLOGY

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CLIMATE represents the average state of the earth's atmosphere with its various components of air chemistry and physics. The chief elements which affect man are degree and variability of temperature, pressure, moisture, radiation (both solar and terrestrial), wind currents and magnetic and electrical states. Of equal importance for the race, though less for the individual, is agricultural climatology, as this concerns intimately the development of tropical food supplies. (See "Geography of the World's Agriculture," by Finch and Baker.)

We have to remember that the temperature of the earth's surface is compounded from direct solar insolation and retained terrestrial radiation. (See Brookes's "Evolution of Climates.") The latter is retained chiefly by virtue of atmospheric dust and moisture. Such dust is projected into the air largely by volcanic explosions, such, in recent times, as those of Krakatoa in 1883, La Soufriére in 1902 and Katmai in Alaska in 1912. Terrestrial and cosmic dust may prove of greater influence on climate than has been generally believed. E. S. King has advanced the idea that the planetary system and nearer stars are surrounded by extensive clouds of dust or some absorbing material which must affect radiation. The climatic results of dust and air moisture can be illustrated by a greenhouse, in which the glass roof permits free ingress of the solar radiation, but retains the terrestrial radiations which are of greater wave-length. It is evident that the angle of incidence has great weight in the penetrating power of solar energy either through glass or through the atmosphere, and the highest degree of insolation will occur where the rays are vertical, that is, for the earth, near the equator.

The chief controlling agencies in local climatic states are solar insolation, land and water aggregations, mountains, and currents in atmosphere and oceans. In the tropic zone insolation reaches its greatest height and constancy. The latter is of particular importance because monotony is one of the greatest foes of human life and achievement, whether it be in mental outlook, social contacts, political régimes or climate. The temperate zones, stretching between the tropics and the arctics, might better be called the seasonal zones because of their revivifying climatic contrasts.

A. Supan ("Grundzüge der physischen Erdkunde," 1896) assigns to the tropic belt that portion of the earth's surface lying between the isotherms of 68°, which roughly indicate the polar limits of palms and of trade winds. This zone widens over the great land areas of the Americas and of Africa. Continental climates, removed from the near influence of oceans, are apt to be more rigorous, with wider temperature range, greater dryness and dustiness. Land areas heat and cool more quickly than ocean areas, hence seasonal changes are greater and the seasons are not apt to be retarded as in oceanic climates. Coastal climate carries marine features a varying distance inland, depending to a great extent on adjacent altitudes and on the prevailing winds. Windward shores incline to a heavy rainfall. Lee shores in the trade belts may bring deserts to the sea, as on the western coasts of South America, South Africa and Australia.

A better understanding of tropical

climate will be achieved with some explanation, even if partly theoretical, of its historic development. It suffices to quote Brookes's "Evolution of Climate" and O. Peterson's theory of the tidal foundation of climatic epochs or cycles. Brookes draws the rule that there is a "basal" temperature for every latitude, to be found near the center of an ocean area in that latitude. This basal temperature is a function of the amount of land in that belt of latitude. In higher latitudes than 20°, greater land areas considerably lower the winter basal temperature and to a less degree raise the summer basal temperature for that belt.

Peterson's theory begins with the observation that the strength of the tides is greatest when sun and moon act in conjunction and are nearest the earth. These fluctuations of strength exhibit cycles, although the actual length of the periods is not constant. Greater range of tides causes greater diffusion of ocean waters by currents and therefore increased circulation between tropical and cold seas. Temperature variations in surface waters of the ocean result in more cyclonic activity and storminess at the times of greatest tidal range. The last maximum, about 1434 A. D., was accompanied by a general increase of storms and rainfall. This observation was confirmed by Huntington's study of sequoia rings in California. The next preceding maximum, about 350 B. C., was the culmination of the period of deposit of the great European peat bog formations, a period which included the time of the seventh century B. C., in which severe climate seems to have destroyed a preexisting north European civilization. Sagas and Germanic myths referred to this epoch as the "twilight of the gods," when frost and snow ruled the world for generations during the Early Iron Age and civilization in northwestern Europe retrograded. Brookes assumes that the present general distribution of land and sea has been constant during historic times and that general climatic changes have been chiefly due to tidal cycles.

The evidence of ruins shows population centers in ancient and prehistoric times where now desert wastes make settlement difficult or impossible. Such examples are seen in Arizona, Arabia, Yucatan, Central Asia and the Sahara. Ellsworth Huntington explains this change on the basis of his theory of shifting climatic belts. He believes that in periods of great storminess in the temperate belts, the temperate storm tracks shifted into sub-tropic belts, pushing toward the equator the high pressure climatic zone and causing cool dry winters, contrasting seasons and stimulating climate in regions which since have been returned to tropical conditions, as these storm tracks returned to the north. (See Huntington, "Civilization and Climate.")

Many geographers do not accept this theory, but it offers, none the less, a useful explanation and points an important proposition with reference to future occupation and utilization of tropical dry regions. It raises a serious question as to the type of colonization, character of industry and reasonable expectation of success, in civilized development of these regions. Progressive desiccation of central Asia resulted in the enormous migrations into China, India, the Near East and Russia, which have changed and controlled political and social conditions down to this day. Present extension of the Sahara, restriction of agricultural lands in Palestine and Syria, and indefinite availability of Mesopotamia for agriculture, are examples of the need of taking into account the history, evolution and tendencies of climatic change, in planning for human occupation of tropical arid areas.

Human achievement is not consummated by defying and conquering the forces or the laws of nature. Invariably it is won by understanding and utilization of those laws. In human adaptations to climatic and geographic facts the same principle holds. Jean Brunhes ("Human Geography") well says, "It is better to content one's self with a half victory over natural agents rather than to expose one's self to defeats which are catastrophes." All too often the feats of civilization are not in accord with natural phenomena and are thereby doomed to destruction, even sometimes increasing the disastrous force of nature. Brunhes points out the enormous influence on the destinies of man of certain fundamental geographic facts, the "sovereign masters of men," which he summarizes as space, distance and difference of level. These "tyrannical factors of human geography" must be taken into account with the utmost consideration by those concerned with the future development of the tropics. Space now occupied and space available for occupation must be surveyed and studied. Distance means traffic and communications, with all the factors that facilitate and impede each, including native customs as well as natural phenomena. Difference of level brings into account the enormous potential forces of water-power, irrigation and climatic changes associated with altitude.

Man has reached his highest development in temperature zones, but nature is most prodigal in hot climates. Hence for his future, more and more, man must turn to the tropics for food and other resources. Medical science has its task in controlling and understanding tropical disease hazards. These hazards are inherent in the tropics and pertain to the natural phenomena of the tropics, to place and circumstance, and not to race.

The outstanding feature of tropical climate is its uniformity, lack of seasonal variation, and only local periodic weather changes, chiefly associated with the diurnal and annual variations in solar influence. The great exception to this rule is found in tornadoes, which will be discussed separately. In the tropic zone, mean temperatures are high, as stated above, lying between the isotherms of 68° and very largely included within the isotherms of 80° in tropical islands and to a considerable extent also on tropical seas. The warmest belt of latitude is 10° North. In most of this zone the mean annual range is not over 10°, on the edges approaching 25°, and on the oceans often not over 5°.

Tropical "seasons" are classified by rainfall and prevailing wind. The rains tend to follow the vertical sun, and therefore to show two maxima, as the sun is vertical both in April and in September. This is the equatorial type of rainfall. It is easily and frequently disturbed by local features of the geophysical relief, by monsoons and by the trade winds. Outside the equatorial type is found the "tropical" type of rainfall, where, as R. de C. Ward says, "the trade belts are encroached upon by the equatorial rains during the migration of these rains into each hemisphere," following the height of the sun. There are still two periods of vertical sun, but they come so near together that the maximal rainfall periods tend to merge, giving a wet season and a dry (or drier) season, that is, one maximum and one minimum.

The heaviest belt of rainfall is in the tropical doldrums, where barometric pressures are low, and where calms, squalls and light, baffling winds abound. Thunderstorms and heavy downpours tend to a diurnal periodicity, the sky is prevailingly overcast and cloudy, and the air is muggy and oppressive. The great tropical forests of central Africa and Amazonia are fostered by these conditions. Bright skies and tempered prevailing breezes are found, by contrast, in the tropical belts just outside this equatorial strip. Here the rotation of the earth sets up the great north- or south-easterly trade winds in the latitudes from 10° to 25°. Between 25° and 35° is found the belt of tropical calms, the "horse latitudes." Beyond these comes the region of steady prevailing westerly winds. (See Fig. 68, p. 212, Huntington and Cushing, "Human Geography.")

It remains to call attention in the temperate zone belts of westerly winds to the characteristic occurrence of cyclonic storms, where a low pressure area five hundred to a thousand or more miles in diameter causes winds to blow toward their centers. These winds are deflected into a spiral or revolving direction. These storms are of immense health value by virtue of their rainfall, lowering of temperature and wide atmospheric disturbance. In them the air moves toward the central area of low pressure and then upward. In their accompanying anti-cyclones an area of high pressure causes the air to move downward so that it becomes warmer, holds moisture better and therefore is not accompanied by clouds and rainfall. These also cause constant changes of weather, which are beneficial to health. Intense cyclonic storms in the trade wind zone are often of small area and very destructive in their effects. These are called hurricanes. Since the earth's axis is inclined to the plane of its orbit, seasons are produced as the vertical rays of the sun, followed by all the climatic belts, migrate between the latitudes of 23° north and south. (See Huntington and Cushing, "Human Geography," Fig. 70, p. 219.)

In general, tropical and subtropical seasons are classified by and consist of changes in rainfall. Temperate seasons depend on temperature changes, with abundant precipitation in all seasons. Huntington and Cushing point out that for this reason inhabitants of these regions are more widely distributed and resourceful than elsewhere, as, for instance, in the arid regions of the tropical high pressure belts.

ALTITUDE

Elevation of land plays an important rôle in tropical climatology. Variations of winds, temperatures, storms and barometric pressures are introduced by increased altitudes, resulting in a more stimulating and healthful climate in plateau and mountain regions. In general, tropical mountain climates follow the rule of lower temperatures; more variability of temperature and abundant cloudiness and rainfall. The effect of increased insolation is relatively greater than in higher altitudes because of the vertical sun. Often these uplands are closely adjacent to unhealthy lowlands and their utilization for holidays or even for regular residence adds greatly to the health and comfort of those whose occupation is in the lowlands.

Each 330 feet of altitude in summer and each 400 feet in winter connotes a 1° decrease in temperature. Hence large high land areas favor glaciation, as on the Ruwenzori of central Africa and on the Andes. In addition to its effect in lowering temperature, altitude also decreases barometric pressure and absolute humidity. On the other hand, insolation and radiation rapidly increase. The lack of moisture and dust in the atmosphere are important aids in this. In cold seasons and at night the cold air from aloft flows down on valleys and plains and is replaced by the warmer air from below. In hot seasons and in the daytime there is an ascending current. In determining the health effects of altitude we have to consider the degree of insolation (that is, the latitude and the degree of elevation), the amount of cloudiness, local topography, winds and resulting local humidity, as well as variability of climate. The effects of drying (due to dry air and winds), lowered pressure and increased sunlight are very definite. Excessive drying is even more harmful than excessive humidity, except under conditions of very high temperature. Sun-glare and extreme drying qualities are important elements in making highlands less available for human habitation.

As locations for permanent residence

it is not possible, however, to assume that tropical highlands are completely healthy or to compare them equally with elevated regions in temperate latitudes. In other words, we can not say that altitude completely neutralizes and compensates for the chief characteristics of tropical climate; *i.e.*, humidity, low barometric pressure and high temperature. There is another group of considerations of the utmost importance. Habitable altitudes in the tropics share in the great tropical characteristic of excessive climatic monotony. This is not so pronounced as in the lowlands, but it remains a factor of hygienic importance. The danger of breakdown under hard work is very imminent. The nervous system suffers and, for whites, acclimation without deterioration is most difficult. Few definite observations and figures are to be had and the matter is worthy of serious investigation. Tendency toward nervous and mental breakdown is to be expected from long residence in tropical highlands, or else a progressive inertia and mental deterioration. Geographically these regions impose other handicaps, such as difficulty of communications and human circulation, isolation, and, as always in the tropics, close contact with native races whose influence is definite and debilitating. The general features of tropical psychology apply here as in the lowlands. It is safe to assume, therefore, that tropical altitudes afford valuable sites for recreation and vacation for tropical workers in the lowlands; that, whenever it is possible, residence in the highlands is preferable to residence in the lowlands; but that permanent residence in tropical highlands offers serious dangers and is a subject needing much greater study. The abundance of causes and of vectors of disease in low areas tends to drive man to higher altitudes for his chief settlements, as we see in the history of Central and South America. Mountain sickness and thin atmosphere tend to keep him from going to excessive altitudes. The great ancient civilizations of the tropical Americas were at moderate altitudes and there to-day is where the denser population is found.

VARIABILITY

No element of climatic influence on man takes precedence over variability. Conversely, monotonous climate is among the chief enemies of man in the tropics. Physical and psychical energy decline in the absence of climatic stimulation. Mental, physical and moral health decrease, lacking the tonic invigoration of climatic change. The great virtue of temperate zones lies not in less heat, less humidity and less insolation, but in the advantage of seasonal and diurnal changes of weather, including the effects of cyclonic storms. The evident favoring influence on civilization and human energy is an index of this relationship. Perhaps climatic monotony is the white man's greatest tropical handicap.

For practical uses we can omit more than reference to climatic cycles which have been noted previously. Lack or insufficiency of seasonal change in the tropics is inherent in the low latitudes. Cyclonic storms are represented almost wholly by hurricanes which are local and infrequent. The common thunderstorms do not materially alter temperatures.

Variability in climate has a definite and considerable effect on the development of resistance to disease. Tropical monotony therefore paves the way for disease. At the same time it furnishes conditions of constant high temperature and moisture advantageous for the propagation, vigor and survival of pathogenic bacteria and other microorganisms, as well as for the optimum growth of vectors.

It is doubtless true that climate has not received due consideration as an important factor in civilization and individual character. The element of variability takes high rank in climatic influences which to a surprising extent control human energy, civilized advancement and individual achievement.

LIGHT

Tropical light is part of the more general subject of tropical insolation. It affects man by two methods, (1) the influence on general climatic conditions, constituting what is called solar climate, and (2) direct effect of radiation on man himself.

1. The general effects on tropical climate have been noted, with the peculiar double maxima of insolation and rainfall which are found between the latitudes of 12° north and south. At the latitude of 15° these have merged. Insolation is controlled especially by the obliquity of incidence of the sun's rays, by the thickness or density of the atmosphere, and by additional substances in the atmosphere such as dust and moisture. Of the sun's energy impinging on the atmosphere in the tropic zone, two fifths to one half does not reach the earth's surface.

2. The question of the nature and degree of the influence of insolation on man is far from clear. The chief difficulties in arriving at a solution of the problem are (1) the length of observation necessary, requiring many years or even several generations; (2) the close association of other complicating factors of tropical life and climate; (3) the need of subjects free from disease and with normal blood and nervous systems; (4) unknown reactions due to race, degree of pigmentation and psychologic status, and (5) difficulty of securing adequate controls. C. W. Woodruff ("Effect of Tropical Light on White Men") lays the backwardness of mankind in the tropics to excessive insolation, which first stimulates and then disorders the human organism. The actinic, or ultra-violet, section of the spectrum of sunlight is held at fault by him. Woodruff's book should be read, but with a careful regard for the five criteria just noted. There is much experimental and clinical evidence that the actinic element of sunlight does have an initial stimulating effect on tissues exposed to it, an effect distinctly different from the red or heat rays. Skin directly exposed to the sun reacts at once to the heat rays with a mild erythema. The same effect takes place through ordinary glass. But direct exposure is followed in three or more hours by "sunburn," a result not obtained under the protection of glass, which absorbs the actinic rays. It has been shown that the reaction of the skin to chronic insolation includes pigmentation, which thus becomes a protective mechanism. Chalmers and Castellani ("Manual of Tropical Medicine") refer to a case of leucoderma in a tropical native who suffered severely, when exposed to the sun, from nausea, vertigo, weakness and local pain.

The effect of light on the constituents of the blood has entered a new chapter with the researches of A. F. Hess, H. Steenbock, Kugelmass and MacQuarrie (*Science*, September 19, 1924) and others on the activation of blood lipoids by radiation with sunlight. While these studies have been largely concerned with the cure and prevention of rickets, they open a suggestive field in general nutrition and general physiology. Hess (*Jour. Am. Med. Assoc.*, April 4, 1925) refers to the common knowledge among botanists of the influence of the actinic rays of the sun on plant physiology, to their deleterious effect on bacteria and to Finsen's observations on their beneficial action on certain skin eruptions, as in lupus. Rollier has been largely responsible for the use of heliotherapy (utilizing the ultra-violet rays) in the treatment of tuberculosis of bones and glands. Finally it was demonstrable that rickets was a direct result of insufficient ultra-violet radiation, resulting in deficiency and disturbance of calcium and phosphorus metabolism. Hess summarizes our knowledge of their physiologic effects as follows. They have remarkably little power of penetration. They are easily absorbed by dust, smoke, fog and moisture in the atmosphere. The average or total annual or seasonal amount of sunlight does not determine the amount of ultra-violet rays reaching the earth, but rather the vertical incidence of sunlight when the actinic rays are not so largely absorbed in the atmosphere. Thus while temperate zones may have a greater number of annual hours or days of sunlight than do the tropics, especially in winter there is a deficiency in ultra-violet rays with a definite increase in rickets.

It is possible to activitate certain foods by ultra-violet radiation so that they develop the same anti-rachitic properties as those of cod-liver oil, as, for instance, dried milk, certain cereals, meat, egg yolk, refined flour, certain leafy vegetables and vegetable oils. This anti-rachitic element resulting from irradiation has been called Vitamin D, but there is much uncertainty as to its being a separate substance. It is associated with lipoids of the nature of sterols, as cholesterin. Hess has suggested that cholesterol may be the chief substance capable of activation by radiation. At least we know that radiation of the skin affects the whole body. Cholesterol is especially abundant in the outer skin, is carried in the blood stream, and is found in the tissue cells. Hume, Lucas and Smith (*Biochem. Jour.*, xxi, 362, 1927) have shown that Vitamin D can be secured in sufficient quantity by the body through the medium of inunctions of irradiated sterols.

It is equally true that the invisible actinic rays have a destructive action, when their intensity is relatively excessive for the substance radiated. Exposure of eggs and embryos of lower animals leads to development of monsters, freaks, one-eyed fish and numerous abnormalities of structure. Marie Hinrichs believes that death and distortion are produced by excessive exposure to these rays because they tend to attack the strongest points of living matter, where life processes are most active, where vitality is chiefly centered. There is need of experimental data along this line as to the influence of tropical light on developing and growing human child life and on perversion of physiologic processes in adult life. Radiation of milch cows has been shown to increase the Vitamin D content of the butter fat, but C. E. Bills does not find the same result when fish are exposed to ultra-violet radiation. He suggests that some unknown biologic mechanism comes into play in the fish liver to activate the oil.

In considering the effects of tropical light, we are brought face to face with a difficult, poorly understood and highly important subject, the photodynamic action of radiation. Bovie (*Oxford Med.*, iii, 368) says that "there is for most living things an optimum intensity of illumination which is a necessary condition for the maintenance of a normal reaction between the organism and its environment." This optimum varies for different plants and animals. Muscle-tone of animals is produced by light and in insects, at least, conditions their phototropic reactions. The chemistry of the retina illustrates the highly developed nature of this "chemistry of light," but its mechanism is poorly understood. "The protoplasm at the tip of an ordinary oat seedling is even more sensitive to light than is the human eye" (Bovie). Probably the cell nucleus is more sensitive to radiation than cell cytoplasm. Growing cells seem more sensitive than when mature or at rest. Here is more than a suggestion of explanation of the pernicious effect of tropical climate on infants and children, perhaps even on intrauterine life.

It is true in general that only absorbed radiations modify protoplasm. Alteration in chemistry as a result of radiation, therefore, means first absorption of rays, and secondly, presence in the protoplasm of photosensitive substances. After a latent period, with simple lapse of time, or on the addition of a new chemical or physical impetus or stimulation, alteration will occur. This is demonstrable in the case of simple tissues and simple organisms. Bovie exposed egg albumen to ultra-violet light at 0° C. with no visible change in its constitution. At any time up to a month and more later, warming up to room temperature caused immediate coagulation. It is probably even more true when we attempt to trace the results of insolation in a tropical population and especially in persons not acclimated in the tropics. The slowness of the alterations produced, their consummation by secondary stimuli of many, and often unknown, natures, together with the numerous other factors which tend to distort the picture, altogether account for the extreme difficulty of studying the real effects of insolation.

Certain known diseases, in which structure and function are grossly disturbed, have been related to solar radiation. Among such are, for instance, Xeroderma pigmentosum of Kaposi, sunburn pigmentation, the rash of pellagra, the light-engendered rash that sometimes follows the eating of buckwheat and other substances, migrainal sneezing on going into bright sunlight, the influence of sunlight and red light on some febrile eruptions, possibly sunstroke and tropical neurasthenia. Pearce and Brown (*Journ. Exper. Med.*, April 1, 1927) have reported a suggestive study of malignant disease in animals, indicating a correlation between light and the manifestations of malignancy. For it has been shown that sufficient ultra-violet radiation is essential for life and for health, but excessive or deficient radiation leads toward disease and death.

It remains to mention another type of light exposure which may be of special importance in the tropics. D. S. Macht has shown some remarkable effects produced on chemical and physiologic processes by polarized light. In polarized light the vibrations all lie in one plane. Such light is indistinguishable to the eye from ordinary light. This quality is found especially in reflected light, as from water surfaces, glass, tin and moonlight. It promotes the conversion of starch into sugar, stimulates growth of bacteria, seeds and sprouts and yeasts, and perverts or changes the activity of certain drugs, as digitalis, quinine and cocaine. It causes greater susceptibility in sick or poisoned rats. If followed by ultra-violet radiation, it caused convulsions and death. These results are very suggestive and open a huge field of tropical research which thus far has not even been touched.

WINDS OF SPECIAL TYPES

1. *Trade Winds.* These winds blow uniformly and steadily from the subtropical high pressure belts, 25°–35° latitude, toward the low pressure equatorial belt. The subtropical high pressure belts are regions of calms. Out of them blow the trade winds in a south- or northwesterly direction (with reference to the equator), to be lost in the low pressure calms and doldrums at the equator. Contrast in pressure belts and the deflecting action of the earth's rotation cause them. The name is not derived from the reliability of these winds and their furtherance of commerce or trade, but is the one use of the otherwise obsolete meaning of "a course or way or direction." It is therefore a wind blowing in one direction or "trade," from the east toward the equator. Their area of chief effectiveness is between 3° and 35°, north latitude, and from the equator to 28° south latitude, shifting somewhat with the season, as all the surface winds tend to follow the vertical sun. They are most uniform over the oceans, where they are not modified by land

masses and mountains. Their importance in transportation has decreased with the decrease in sail-power. The development of air transport may again utilize them. Columbus by chance was brought by northeasterly trades to America.

Airplane transit of the Atlantic from America to Europe is facilitated by the northern belt of westerly winds, sometimes called anti-trades, because they blow in the opposite direction. As a climatic factor the trade winds are of the utmost importance. Moving horizontally with the earth, they undergo little change in expansion and hence their moisture-carrying power is not decreased. Blowing toward a warmer region, their moisture-holding power is increased. As a result the trades are dry winds and attended by a high percentage of clear skies. Similar reasons make the sub-tropic belts of high pressure very dry, in fact the driest in the world. Here the descending air is becoming warmer as it approaches the earth and is so devoid of moisture that it causes rapid evaporation from the earth's surface. The rapidly rising and cooling air of the equator on the contrary results in heavy diurnal rains. These equatorial, tropical and subtropical regions are thus seen to have the elements of remarkably little climatic change, of regular heavy diurnal rainfall near the equator, and increasing steady dryness toward the subtropic high pressure zones. This monotony of wind current is added to monotony of temperature and of rainfall. In the higher temperate zones, cyclonic storms serve an invaluable purpose in promoting changeable weather. In the low latitudes, only special winds induced by local land-water relations, hurricanes, and, to a very slight degree, thunderstorms, are available for this purpose. It is to be remembered that the trade winds in general are most constant on oceans and against easterly shores, and that their general climatic effect is greatly modified locally by high mountains or large land areas.

2. *Monsoons.* Following the suggestion in the last sentence of the preceding section, we find a general rule that large land areas cool more in winter and heat more in summer than do oceans. The general result is relatively high pressures in winter and low pressures in summer. Summer continental rains result from the inflow of moist air currents from oceans into these low pressure areas. In the huge expanse of Asia, these winds and rainfall conditions are exaggerated. Even in southern Persia and western India, annual temperatures have a 100° range, while in Siberia the range may amount to 175°. (Huntington and Cushing, "Human Geography," 235). This is because of the huge size of the continent and results in a heavy inflow of warmer ocean winds in summer, carrying moisture, and a heavy outflow of drier colder winds in winter. These general currents are called monsoons, derived from the Arabic word "mausim," meaning a time or season. They are therefore seasonal winds. They are best developed in India. Because of their origin, there is little winter rain across India and parts of China, when their direction is from the interior. With the establishment of the summer monsoon from the south and southwest, rainfall is heavy. There is a singular regularity in the winter northeast monsoon and the summer southwest monsoon in India. This periodical wind is utilized in sail travel and commerce between India and the islands of the Indian Ocean and Africa. Since the southern tip of India receives the trade winds from the ocean, it receives also a fair winter rain. Otherwise India parches in drought until the summer monsoon brings the rain, together with great improvement of general health conditions. The monsoons entirely control the climate of southern and eastern Asia.

Local monsoons are found also in Australia, the southern United States, southern Africa, and the Gulf of Guinea and equatorial Africa, where to some extent they modify the trade winds.

3. *Hurricanes and Tornadoes.* Cyclonic storms are characteristic of the belts of westerly winds in latitudes 35°–70° north and south. They are responsible for the rainfall and healthful variability of these zones. In the belts of the trade winds severe storms of a cyclonic type occurring at irregular times are called hurricanes. Very severe storms of a more limited area and concentrated nature are called tornadoes. The nature of these latter storms has been best studied by I. M. Cline (Tropical Cyclones), whose description is followed here. Wind forces at the earth's surface represent a combination of (1) those forces, modified by resistance encountered, which act on the inflow of air toward the cyclonic center, together with (2) the general air current in which the entire storm is moving. The tendency to spiral incurvature around the center is greatly modified in travelling cyclones (hurricanes) and is not uniform toward and around the center as usually described. There is, however, a symmetry of isobars for a considerable distance from the center. Winds in the right rear quadrant tend toward the direction in which the cyclone is moving. In the right front quadrant, the inclination or incurvature toward the center is decreased, and the average path becomes equidistant from the center. On the left, the winds come around with increasing inclination toward the center as they pass to the rear, curve into and take the direction of the winds of the right rear quadrant. Thus the essential feature is that the winds at all elevations up through the level of the cirrus clouds move forward in the same general direction in which the cyclone is moving. Thus the momentum of the general air current is added to the velocity and strength of the cyclonic winds of the right rear quadrant. This causes the sustained velocities so characteristic of that portion of hurricanes. Thus it is evident that danger and damage lie in the right rear quadrant while the left side is harmless. The right front quadrant is not so severe as the rear quadrant.

The general path of the storm is determined by air currents in the cloud levels. These in turn are greatly influenced by adjacent anti-cyclonic areas of high pressure. While high pressure areas augment the air current in which the cyclone is travelling, it will continue to advance. If high pressure areas oppose it, the cyclone gradually fills up and disappears. Cline's study of the isobars of three major cyclones showed them to be nearly circular from the center out to the isobar of 29.4 pounds' pressure. Beyond this there was a crowding on the one side and a spreading on the other.

Rainfall is very light in the rear half of a cyclone (hurricane) and heaviest sixty to eighty miles in front and to the right of the center. Relation of land and water areas controls the intensity of rainfall but does not affect its position in the cyclone. Temperatures show little variation. The source of rainfall as well as of cyclonic energy lies in the winds of the right rear quadrant. In the larger cyclones these air streams have a depth of five or more miles, a width of 250 to 400 miles, and a length of 400 to 800 miles in the line in which the cyclone is moving. The storm as a whole advances from 8 to 16 miles per hour and the winds of the right rear quadrant come into the right front quadrant with sustained velocities near the earth of 80 to 100 miles per hour. For 400 miles to rear of the center, velocities of 30 to 40 miles per hour may prevail. From the dynamic point of view the momentum of the great wind currents is more important than the relative positions of high and low pressure. There is low pressure and calm at and near the center. The intensity of tropical cyclones is chiefly affected by low latitude and abundant sources of moisture. They are fostered by the extreme differences in temperature between land and water areas in the tropics.

The tropical cyclone is preceded by a period varying from several hours up to two or four days by heavy tides and storm waves in the ocean. These may be 500 to 1,000 miles distant from the center of disturbance and often are extremely severe and destructive. The tidal rise precedes fall in the barometer and is an important means of predicting the intensity and direction of a tropical cyclone. Such a storm tide means simply a rise in tide and water-level.

Tropical cyclones were first termed hurricanes in the West Indies, from the Caribbean word "huracan." The term then was used in the East Indies and the China seas, where the word typhoon is also applied. Tornadoes, small severe twisting cyclones, are especially common in the Mississippi Valley. Their area and duration are very small although they may do great damage in a narrow path.

Tropical cyclones of all types are important primarily for their great danger to human life and property. Their influence in moderating conditions of tropical climate is valuable but limited by their relative infrequency and narrow localization.

4. *Miscellaneous Special Winds.* The Föhn is a warm dry wind blowing down the Alpine valleys with great force and most common in winter. Very similar to this is the Chinook, which moderates the temperatures of the eastern slopes of the Rocky Mountains. It descends as a warm dry wind in winter, rapidly melting the snows, while in summer it cools the overheated temperatures. In southern France, especially in the delta of the Rhone, the cold dry Mistral blows down from the high pressure of the central French plateau to the warm Mediterranean Gulf of the Lion, even extending so far as Genoa. In Provence and Languedoc it is strongest and blows on an average of one day out of two. It is characterized by intense bright sunshine and piercing cold, and under special conditions becomes of stormy violence. Precisely similar to the Mistral is the Bora which blows on the Dalmatian and Istrian coasts of the Adriatic. From December to February the upper Guinea coast is visited by a hot, very dry wind from the Sahara carrying a heavy haze of red dust, called the Harmattan. Its extremely parching quality leads the natives to anoint themselves with grease during this season. It really belongs in the group of Sirocco winds.

Much confusion exists in the use of the word Sirocco. One type under this heading is the ordinary wind of the Mediterranean winter rainy season. The more widely used meaning, however, especially in Sicily and southern Italy, refers to the dry winds from the Sahara, laden with dust and sand. In the general region of the Mediterranean there are many local names for winds of this type, as Simoon (especially in Syria, Algeria and Arabia); Khamsin (filling the Egyptian air with sand in March, April and May); the Leste (in Madeira, drying the country-side and filling the air with fine red sand); the Leveche (wrongly called the Solano, a dry hot wind blowing on the Spanish Mediterranean coast).

Local peculiarities of land relief give rise to many winds of local importance, too numerous to list, like the "Wind of a Hundred and Twenty Days," in Eastern Persia, that blows for 3 to 4 months, distorting vegetation and making human life arduous. Such steady hard winds are deadening to human initiative and comfort, and produce irritability and even irresponsibility. The discomfort, apprehension, restlessness, nervousness and over-stimulation experienced in many storms and winds may be a composite of actual pressure with poorly understood changes in the electrical and magnetic state of the atmosphere. Under tropical conditions, monotony of any sort is among man's greatest foes. Monotony of wind, of rain, or of temperature is equally disastrous.

5. *Wind Power.* This section can not be closed without commenting briefly on a situation of considerable weight in the future of the tropics. Steam-power from coal and oil, electrical power from steam and water, have come to occupy a primary position in twentieth century civilization. Wind power has been relatively neglected where formerly it was almost man's only source of energy. With the great prevailing winds of the tropics and the special local winds of fair reliability and force, it may well be that utilization of wind power can be made a productive economic asset in many regions now backward because of lack of power for industrial pursuits.

OCEAN CURRENTS

Air friction on the surface of the ocean sets in motion currents whose momentum increases in proportion to the strength and steadiness of the winds. Consequently in the region of the trade winds we find the strongest movements in the water, called the equatorial currents. These are deflected by the continents. The Atlantic north equatorial current is joined by half of the south equatorial current, which divides at Cape Roque, and swings into the Gulf of Mexico. It leaves the gulf through the Florida-Cuban strait and as the Gulf Stream flows northward until deflected by the eastward continental extension, by the Labrador current and by the zone of westerly winds, it swings across the north Atlantic toward Europe, where it spreads out as the Atlantic Drift, warming the entire western coast. In the Straits of Florida this is the strongest and most definite of the ocean currents, narrowing to a width of forty miles, with a depth of 2,000 to 3,000 feet and a speed of five miles per hour.

For the general trend of the major currents a special text and maps should be consulted. In each of the great oceans, there is a general current whirl set up similar to that of the north Atlantic. Ocean currents exercise a profound influence on climatic conditions, by carrying warm water into cooler areas and *vice versa,* thus in turn affecting air temperatures over them, influencing winds, evaporation, precipitation, and diurnal as well as seasonal changes. The high specific heat of sea-water allows minimal diurnal changes in temperature, thus making it a modifying factor in continental climates. Its heat is received entirely from the sun.

COSMIC METEOROLOGY

Cleveland Abbe has excellently summarized this subject in the following words: "Under this title (Cosmic Meteorology) have been included all possible, plausible or imaginary relations between the earth's atmosphere and interplanetary space or the heavenly bodies. The diffusion to and fro at the outer limit of the atmosphere, the bombardment by ions from the sun, the explanation of auroral lights and magnetic storms, the influence of shooting stars and comet tails, the relation of the zodiacal light and the Gegenschein to the atmosphere, the parallelisms between terrestrial phenomena and the variations of the solar spots and protuberances, the origin of long or short climatic periods, the cause of special widespread cold days, the existence of lunar or solar gravitation tides analogous to oceanic tides, the influence of slow changes in the earth's orbit or the earth's axis of rotation—all are grouped under cosmic meteorology. But, in the writer's judgment, these matters, while curious and interesting, have no appreciable bearing on the current important questions of atmospheric mechanics." These matters must be relegated to the physicists for further study and information. Such is true, for instance, in the case of the cosmic rays, recently discovered by R. A. Millikan, whose intensity is tremendously greater than that of X-rays; which are appreciably absorbed by the atmosphere though capable on mountain tops of penetrating six feet of lead, and which may eventually prove to be closely related to problems of altitude sickness and physiology.

MAN'S BEST CLIMATE

We have first to decide on a definition of the best climate for man and then estimate the approach of any tropical conditions to this standard. The pleasantest climate may not be the most healthful or the most effective for physical and mental vigor. Huntington deduces certain criteria for the climate most favorable for work and health, along the following lines. The mean temperature should not exceed the physical optimum of about 38° F. An annual average of some 51° would therefore be most desirable. As general examples of this temperature, Huntington notes England and the Pacific coast of the United States, where western breezes blow. But to proper temperature must be added moderate humidity. Wide temperature variations by seasons are important and usually are accompanied by wide diurnal variations. The influence of cyclonic storms has been noted.

It is evident that the tropics are seriously deficient by each of these criteria. A review of history again drives us to the conclusion that tropical environment in general does not provide the best climate for man's health, advancement or continued pleasure. When we turn to the poorly understood factors of insolation, magnetic conditions, social contacts and psychologic racial reactions, we have, apparently, further evidence of undesirability. Even tropical highlands offer definite hazards and handicaps. For white man or even for natives of temperate climates in general, we can not now assume an ability to maintain health, physical or mental vigor or to procreate healthy children who shall grow to mentally and physically vigorous adulthood in any tropical climate. The student of this subject should review Huntington's discussion of his map of climatic energy ("Civilization and Climate").

CONCLUSION

Willing or not, man's future on this planet requires the utilization of the tropics. He is therefore faced by the necessity of adapting himself to tropical climatic conditions in order to provide for his own future. This imposes the burden of a more rigorous study than heretofore of tropical climatology, which, unlike positive disease causes, can not be controlled, and therefore must be robbed of its dangers by means of accommodation thus far but poorly understood.

THE TREND OF MODERN PHYSICAL SCIENCE

By Professor JAKOB KUNZ

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We may approach this subject by a comparison between the physical world picture of the end of the nineteenth century and the present picture. Toward the end of the period of Helmholtz and Lord Kelvin the material universe was considered as made up of material particles, atoms, molecules, electric charges and magnets imbedded in a universal ether, in which the electric and magnetic energy have their seat and in which light is propagated in the form of waves. The physical space was nearly absolute; time was altogether absolute and independent of space. One universal clock gave to every observer the same time, while one measure stick could be used for all measurements, independently of time and motion. Forces are considered as physical realities. In gravitation we had, since Newton, action at a distance, while in electricity and magnetism the action took place from point to point through the ether along definite lines, the lines of force of Faraday and Maxwell. The methods of theoretical physics were those of total and partial differential equations; mechanical models were used for an intuitive understanding of the physical phenomena. The principle of causality was essentially the old one: If the position and velocity of the material particles are given in a given moment then they can be uniquely determined by means of the differential equations in every following moment; or, more generally, if magnitude and rate of change of the states of the material universe are known in a given moment of time, then they can be determined mathematically for every later moment. Theoretical physics was sharply divided into three departments: dynamics with the fundamental units, centimeter, gram and second; electrodynamics with two further units, electric charge and magnetic pole strength; thermodynamics with one further unit, temperature, and the phenomena of these fields were governed by Newton's equations, by Maxwell's theory of the electromagnetic field, and by Carnot's principle of the second law of thermodynamics. Theoretical physics was a sunny garden under the heaven of mathematics. Two principles especially seemed to dominate all physical phenomena, that of least action and that of probability in the heat phenomena. Though the division of the phenomena into three departments was artificial, violating our feeling of the unity of nature, in spite of several logical defects that period of physical sciences is now rightly called classical.

The classical literature of continental Europe was followed by the romantic period and the classical theoretical physics gave way to the present theory which has many romantic features. Let us now try to outline the present world picture as it has emerged from the theory of relativity and the quantum theory of light phenomena, theories which determine the present trend of physical sciences.

Space and time have become relative and closely linked together. The physical phenomena reside in a four-dimensional non-Euclidian continuum. An infinite number of clocks and measure sticks are necessary for the physical measurements, but they are related in definite ways. The ether has disappeared. Matter consists of isolated positive and negative charges. Matter is reduced to electricity. Chemistry with all its wonders has become a department of electricity. The electric charges have their seat in that four dimensional continuum of relativity. Every motion is relative, even rotation. Whether a glass filled with water rotates on a table or whether the whole universe rotates about it, the observed phenomena are the same. The centrifugal force and the force of gravity are only fictive forces; indeed, they have disappeared altogether. Instead of forces we have to consider the curvature of a space-time continuum, in which all motions take place along geodesic or shortest curves. Dynamics is reduced to kinematics. By a fortunate circumstance Newton's equations with their forces can still be used as a first approximation to the physical reality. Maxwell's equations are still retained as rules of calculation. So the trend is away from mechanical models and intuitive understanding toward a mere algebraic formulation or analytic expression of the laws of nature. But in the theory of relativity the absolute laws of nature are more deeply comprehended than in the earlier theories; anthropomorphic features such as forces have been eliminated and the whole theory is a beautiful logical structure of sublime height.

Entirely different is the present quantum theory in its various phases. It involves a large variety of phenomena, and is in sharp conflict with the older continuum theory as well as with relativity. This theory is due to M. Planck, who in 1900 introduced in the theory of radiation of the black body a new constant h, so that an elementary oscillator like a small antenna in wireless telegraphy emits light only in definite quanta in a discontinuous process; the energy of the oscillator changes by a quantity which is equal to the constant h times the frequency of light emitted. So Planck was able to account for the radiation of light from hot bodies, such as the filaments of incandescent lamps. Since the beginning of this century we have had two conflicting theories of light: the wave theory for the geometrical phenomena of light, reflection, refraction, dispersion, polarization, interference, diffraction and the rotation of the plane of polarization and the quantum theory for the emission and absorption of light, and for the electrical and chemical effects of light. Whenever light arises or disappears, it behaves as if it were made up of particles, $h\nu$, but when once freed from the bonds of matter it seems to propagate in waves. In the sources and sinks light seems to consist of definite units, but in the space between the sources and sinks it behaves as a wave motion. This property of light is directly illustrated by the photoelectric effect. When light falls on alkali metals, for example, electrons will be emitted. Their number depends on the intensity of light, their initial velocity on the color or frequency of light. No matter how weak the incident light may be, the electrons are emitted with the same velocity for a given color of light, just as if the light consisted of definite particles whose energy only depends on the color or frequency of light. And as in the emanation theory of light the intensity decreases with the square of the distance from the source, so in the photoelectric effect the number of electrons emitted decreases with the square of the distance from the source. The intensity of light only affects the number of electrons emitted, not their velocity; the color of light only affects the velocity of the electrons. This contradicts all mechanical explanations on the basis of a wave theory. In the case of electrons emitted under the action of Röntgen rays, the effect is still more pronounced. It looks as if the whole energy of a moving electron was transmitted through the Röntgen ray to another electron originally at rest without loss. A mechanical analogy would be this. A stone falling from a certain height in the Atlantic in the neighborhood of New York would produce a system of waves spreading throughout the ocean and reaching the coast of England would raise a stone of the same weight to the same height! Moreover, it has recently been found that in the scattering of Röntgen rays, the hardness of the rays changes, as if the incident ray had a definite momentum and energy and as if this light particle collided with an electron according to the laws of conservation of energy and momentum.

Niels Bohr has developed a quantum theory of the atom, especially of the hydrogen atom, on the following assumptions. The atom consists of a nucleus of positive electricity, which contains most of the inertia of the atom. Around this nucleus an electron of the same but negative charge circulates in definite orbits. According to our experience with electric waves such a revolving charge ought to emit light. Bohr, however, assumes that this sort of electricity in the atom does not radiate in the stationary orbit, which is either a circle or an ellipse. He assumes further that the stationary orbit is determined by Coulomb's law of electric action and by the quantum relation that the moment of momentum of the revolving electron is equal to the constant h multiplied by an integer, divided by 2π. Finally Bohr assumes that light is given out by an electron jumping from one stationary orbit to another one. This theory has had great success in the interpretation of the line spectra of chemical elements. Bohr has extended the theory to the other elements, assuming that the higher elements are formed by the addition of one electron after another to the corresponding nuclei. So we have gained a new interpretation of the periodic properties of the chemical elements. Additional principles like those of selection, of correspondence, of exclusion, the adiabatic hypothesis have been introduced until a new quantum theory of matter appeared like a new science of considerable size and importance. A very interesting idea, that of space quantization, has been introduced in the classification of the various groups of lines of the elements. And the magneton of the hydrogen atom has been determined recently by means of experiments suggested by space quantization of electron orbits. The various successes of the theory, the explanation of the Zeeman effect, the Stark effect, the resonance and ionization potentials, the fine structure of the hydrogen lines, the coordination of the complicated multiplets, led many physicists to overlook the defects of the theory. Special difficulties arose in the case of the simultaneous action of an electric and magnetic field on the radiation of the atoms.

Within the last two years two new theories have appeared, both of which eliminate the only intuitive character of Bohr's atom, the microcosmic planetary system of electrons in the atoms. One of these theories is a pure discontinuum theory, the other a vigorous continuum theory, and the results of both theories seem to coincide exactly. Such is the power of mathematics. The continuum theory of Schrödinger introduces wave mechanics; the orbits of the Bohr atom are replaced by characteristic or auto-vibrations in a transphenomenal space of which we have no intuitive experience. The quantum conditions of the older theory correspond to the boundary conditions of the problem. This reminds us of the harmony of numbers in Pythagoras lyra. The integers of the triad of the vibrating string are due to the boundary of the string. The vibrations in the atom, however, are metaphysical or transphenomenal. The electron in the atom itself is not a point charge, but its charge is spread throughout the atom or the whole space. And its electricity spins around an axis giving rise to the magneton. It has only four degrees of freedom instead of six, as we should expect from any mechanical analogy.

If anything is not intuitive, it is this atom of Schrödinger. And so we see in relativity as well as in the quantum theory a tendency away from mechanical models toward a purely mathematical formulation of the laws of nature. Maxwell's equations, without an ether and without lines of force, are for me merely mathematical rules of calculation. When we speak of the velocity of light in the theory of relativity, we admit that nothing moves! In a similar way the new theories of the atom are only rules of calculation; Schrödinger speaks of oscillations in a transphenomenal space without even saying what moves.

The pure mathematician still uses models in geometry, he constructs even models of non-Euclidian spaces; the chemist, using a model for the benzene ring and its derivatives, has built one of the richest departments of natural sciences, organic chemistry, but the physicist between the mathematician and the chemist seems to be doomed to resign to all intuitive thinking by means of models. This may be, of course, a temporary fashion of the present theoretical physicists. Nevertheless, I think we shall continue in our instructions to use lines of force as models for electric and magnetic phenomena, rays of light in geometrical optics, valence lines in the chemical compounds as before, forces in mechanics, lines of flow and equipotential surfaces in hydrodynamics.

If theoretical physics should be reduced to a certain number of rules of calculation, without any intuitive understanding of the phenomena by mechanical models, nevertheless I believe it is well to continue to use mechanical models not only as illustrations, but also as tools for further investigations. Some of the most important discoveries have been made by mechanical analogies. Carnot arrived at the second law of thermodynamics by a mechanical analogy; Faraday, the greatest discoverer in physics, was guided by models; Maxwell used mechanical principles in the deduction of the laws of the electromagnetic field. Newton's emanation theory of light led to the conclusion that a beam of light from a fixed star, passing across the limb of the sun, would be bent, and this conclusion should have been tested independently of relativity.

With and without models, deep problems remain to be solved. The abyss between the continuum theory of relativity and the quantum theory still remains open, the constant h has not yet been explained or correlated with Maxwell's field theory; the theory of light is still covered by a dark cloud. But no matter how difficult the problems may be, how contradictory the present theories, the physicists as well as every scientist has the religious conviction that nature is unity and that the laws of nature form a harmony.

THE PHILOSOPHICAL BACKGROUND OF RELATIVITY

By Dr. MORTON MOTT-SMITH

THE distinction between the old philosophical and the new physical relativity is not well understood. Consequently, every now and then the claim is pushed forward that so-and-so has anticipated Einstein, because somewhere in his writings he made some general remarks about relativity, or described in detail the relativity of motion prior to 1905, the date of Einstein's first contribution. Or else it is claimed that there is nothing essentially new in Einstein—that ideas of relativity were common property long before his day. It is time that both these pretensions were punctured.

Four stages of relativity may be distinguished, one philosophical and three physical. The first dates back to the very beginnings of man's reflections concerning the nature of human knowledge. Already Protagoras, "Greatest of the Sophists," contemporary of Socrates, who lived in the fifth century B. C., said: "Man is the measure of all things." He taught that there is no absolute truth, that we know things only as they appear to us through the senses. We have therefore no direct knowledge of the things themselves, but only as they appear to us, colored and distorted by their passage through the senses. What is great to one man is small to another. Man measures and judges everything in relation to himself. The human element in knowledge is inescapable.

In the seventeenth century A. D., the same thought was again taken up by John Locke. He showed that all knowledge arises through the comparison of our sense-ideas, one with another, in respect to their likeness or unlikeness, or other relations in which they may stand to one another. We know a thing only through its relations to other things, and these again by their relations to still other things, and so on. Hence in the end we know only relations. The things themselves forever elude our grasp. In their true and absolute natures, if such exist, they are completely beyond the human understanding. For Locke, all knowledge was derived from experience. "There is nothing in the mind, which was not previously in the senses," he said; and Leibnitz added, "except the intellect itself." The intellect itself contributes something, Leibnitz taught, which is not derived from experience—namely, logic and mathematics. But Kant showed that these are applicable only to the material of experience. When applied to anything else, they inevitably lead to irresolvable contradictions (antinomies). Hence "Pure Reason" provides no bridge to the thing themselves, as they really are before they pass to us through the senses. So Kant divided the world into two parts, the phenomenal and the noumenal, the knowable and the unknowable.

One of the main theses of Herbert Spencer was the relativity of all knowledge. Like Kant, he divided the world into two parts, the knowable and the unknowable, the relative and the absolute. All the former belonged to science, all the latter to religion, or to whomever else might care to claim it.

Of course not every one accepted this philosophy. From Protagoras onward men have incessantly endeavored to get at this entrancing realm of the absolute by some means or other—by pure reason, intuition, faith, inspiration or by some other mystic means. But whatever may be the final outcome of their endeavors, this much is certain, and may be regarded as the one positive contribution of the critical philosophy—all *scientific* knowledge is relative. Logic and mathematics are tools which are applied to the data of experience, which alone furnishes the materials. All else is *un*scientific, and may well be left to those dreamers and mystics who delight to roam the realm where all positive knowledge is impossible, and no facts may refute them.

A part of the relativity of all positive knowledge is the relativity of all knowable motion. This fact was discussed and fully established centuries before Einstein lived. It was very clearly set forth by Descartes in his "Principles of Philosophy" (ii, Par. 18, 1644) in the following words: "In order that the place (of a body) may be determined, we must refer to other bodies which we may regard as immovable, and accordingly as we refer to different bodies it can be said that the same thing does, and does not, change its place." He then gives the illustration of a sailor on a ship, which has been so much used in this connection. The sailor moves on the ship, which moves on the seas, on a moving earth. Descartes shows that finally to determine the true motion of the sailor, we must "determine it with reference to some immovable points in the heavens. But, if we concede that no truly immovable points are to be found in the universe, as I shall hereafter show is probable, our conclusion will be that there is nothing which has a fixed place except so far as it is determined in thought."

Very much the same exposition was given by Newton in the scholium at the end of the first chapter of the Principia (1686) using the same illustration of the sailor and the ship. But contrary to Descartes he believed that "it is possible, that in the remote regions of the fixed stars, or perhaps far beyond them, there may be some body absolutely at rest." But as there is no way to know that this body is at rest it would be of no use to us. "And so, instead of absolute places and motions, we use relative ones; and that without any inconvenience in common affairs." "Yet," he believes, "the thing is not altogether desperate." For he thinks that the forces required or developed by motion, particularly rotation, may be used to distinguish between absolute and relative motion. In short, although the distinction is impossible by direct observation or measurement of motions, it may be possible indirectly through some physical effect. Of this we shall hear more presently.

In 1765, the great mathematician Euler, in his "Theory of the Motion of Solid or Rigid Bodies" (Chapter I), after again discussing the sailor and the ship, said: "The same body which is at rest with respect to the body A is in various motion with respect to other bodies. . . . Therefore motion and rest are distinguished merely in name and are not opposed to each other in fact, inasmuch as both may at the same time be attributed to the same point, according as it is referred to different bodies. Nor does motion differ from rest otherwise than as one motion differs from another." As later physicists have put it —rest is a special case of motion.

In the second chapter, Euler then goes on to discuss most interestingly the question whether, if there were but one body in the universe, this body could properly be said to be at rest or in motion. He answered emphatically—yes. Suppose all the bodies in the universe were removed one by one, until only the earth were left. Would that destroy the motion of the earth? By no means. It would merely remove our every means of ascertaining that motion, but the motion itself would not and could not be destroyed by such an act. The conclusion is strengthened if we apply, as Euler did, Newton's first law of motion. Whatever motion the earth had at the moment of the removal of the last body, must continue thereafter unchanged.

Now if the material universe is finite, as many believe it to be, it constitutes just such a Eulerian single body in space. We can neither affirm nor deny that it moves. But such a motion has no meaning for us. We can only determine the relative motions of its parts.

All of those quoted, it may be noted, while denying the knowability of absolute motion, tacitly assume its existence. Herbert Spencer, in his "First Principles," Par. 57, 1860, specifically argues for its existence. Though he declares it to be not only unperceivable, but inconceivable, incomprehensible and unknowable as well, he maintains that "in this very process of concluding that the motions we perceive are not the real motions, we tacitly assume that there are real motions. . . . that there are fixed points in space with respect to which all motions are absolute; and we find it impossible to rid ourselves of this idea." He uses also the ship illustration.

A diametrically opposite conclusion is drawn by J. B. Stallo, "Concepts and Theories of Modern Physics," p. 200, 1881. On the basis of "the universal principle of relativity" which he proclaims, he affirms that "the annihilation of all bodies but one would not only destroy the *motion* of this one remaining body and bring it to rest, . . . but would also destroy its very *existence* and bring it to naught." For according to Stallo, not only the knowability but the very existence of a body depends upon its relations to other bodies. Destroy the relations and you destroy the body. "A body can not survive," he says, "the system of relations in which alone it has its being."

Finally Hudson Maxim in "The Nature of Matter" (*Scientific American Supplement,* May 11, 1889) came also to the conclusion that absolute motion does not exist. "Let us now conceive," he says, "of but one of these ultimate solid atoms as existing entirely alone in all space. . . . It could have no motion in any direction, for space of itself without limit is without direction, and no place in space could have position relative to the rest of space—hence position and place as relative to but space are impossible, therefore, a single ultimate atom existing alone in space could have no motion, as it could not alter its position, having no position or place to change." It would seem fairly obvious that a body, "having no position or place," that is a body that is nowhere, simply does not exist. But Maxim did not advance to this conclusion as Stallo had done. Both Stallo and Maxim deny not merely the knowability of absolute motion, but its very existence. For this they have been credited by some with having anticipated Einstein. But the conclusion is hardly justified. To deny that a single body in all space can be in motion is to affirm that it is at rest. And this rest is absolute rest. To affirm absolute rest is as pernicious as to affirm absolute motion. To deny either is to affirm the other. We here fall into one of those antinomies which Kant taught us is inevitable whenever we endeavor to penetrate that vacuum that surrounds the world of experience. The only escape from this dilemma is the one that Stallo took, *viz.,* to deny the possible existence of such a single body.

However we are not here concerned with these metaphysical quibbles. Let the philosophers wrangle over them. The lesson for us to learn is that absolute motion whether it exists or not is totally unknowable. Nor does it matter to the scientist whether it exists or not. The only kind of motion that he can deal with is relative motion, the motion of one body with respect to another. This we may concede the philosophers to have definitely established. The conclusion depends upon no experiment, but results from analysis of the knowing or perceiving process itself. No experiment can weaken or strengthen it.

All this was known long before Einstein stepped upon the stage, as our quotations have shown. It has nothing whatever to do with the modern physical theories of relativity. The latter are not derived nor derivable from any philosophical principles. They were not foreseen nor foreseeable by any philosopher. They resulted solely from certain particular experiments. Each of the three stages, in fact, had to fight its way against opposing general notions supposed to be rooted in common sense. No philosophical theories can strengthen or weaken them. Future experiments alone can decide whether they shall continue to stand or not.

What then is the distinction between philosophical and physical relativity? Philosophical relativity, we have seen, is concerned with the knowability and existence of absolute motion. The former has been decided in the negative. The latter is undecided, but irrelevant. Physical relativity is concerned with the problem whether there is any indirect means of determining the motion of a system by means of physical phenomena taking place within the system. That is, can we detect its motion without looking outside? It matters not whether the motion we so seek to detect is absolute or relative. Hence this is a purely physical question which can be settled only by experiment and is independent of all philosophical considerations. We have seen that Newton already asked this question in his scholium, thinking there might be some such means of detecting the absolute rotation of a body. But his argument was fallacious.

The first stage of physical relativity resulted from the experiments of Galileo prior to 1638, although the relativistic significance of them was not appreciated until more than two and a half centuries later. Up to this time it had been supposed that force is required not only to produce, but also to maintain motion. Rest was taken to be the natural state of bodies, to which they invariably reverted as soon as the forces that impelled them ceased to act. Since the earth was supposed to be stationary, this rest was absolute rest. Hence it became an insoluble riddle as to why a stone continues to move for some time after it has left the hand of the one who flung it. (See Descartes, "The World," Chapter VIII). So long as the hand is pushing the stone, it is easy to see that the stone should move, but why does it continue to move after the push of the hand has ceased? In short, why does the effect continue after the cause that produces it ceases to act? Now, Galileo did not answer this question. He merely ceased to ask it, based, as it was, on a false assumption. Knowing that the earth is moving, he knew that the stone was also moving before ever the man acted upon it. The effect of his action was not to produce motion *de novo,* but merely to alter a motion already existing. If the man had thrown the stone in the direction contrary to that in which the earth is moving, he would not have created any new motion, but would have detracted from one already existing. So Galileo reversed the question. Rather, he asked: "Why does the stone once flung ever cease to move with its new velocity?" The answer he found in the resistance which the air opposes. And so with all other bodies, that sooner or later come to rest with respect to the earth, he found the causes in the greater or less resistances which they encounter. The more and more these resistances are diminished, the further and further a given impulse will carry a body. Suppose the resistances could be reduced to an absolute zero—what then? Galileo answered that the body would continue with unaltered velocity and direction forever. And so was born the law of inertia, or the first law of motion, as Newton afterwards called it. This was a revolution of prime importance—the end of old notions, the birth of new ones. A static world gave way to a dynamic one. Not rest, but motion, is the prevailing state. All bodies continue in the state of uniform motion in a straight line, unless compelled by force to alter either their velocity, their direction, or both. The effect of force is to alter motion. Force is required to stop as well as to start a body, to diminish as well as increase its velocity. No force is required to maintain motion.

Here is a state of affairs surprisingly different from what was supposed to obtain, and what is even now supposed to obtain, by those who have never heard of, or having heard, have failed to understand the full significance of the law of inertia. Could any philosopher have predicted it? Did any philosopher foresee it? The answer is: No. It was an experimental discovery. Who could have dreamed that physical motions depend upon differential equations of the second order, as this law demands, instead of equations of the first order, as the previous views require?

The relativistic significance of this discovery may be explained as follows: I use the stock illustration of the train, because there seems to be nothing better. The train, in fact, is getting to be as indispensable to physical relativity as the ship and sailor were to the philosophers. Suppose you were shut up in a windowless train running with uniform speed on a perfectly smooth, straight track, absolutely without noise or jar. There is no mechanical experiment that you could try that would in any way disclose your motion. In other words, everything would take place exactly as though you were standing still. If you throw a ball vertically upwards, it falls vertically downward into your hand again. It is not left behind by the forward moving train. For, by the first law of motion, the velocity of the train, which the ball had when held in your hand, is preserved unaltered, after leaving the hand. So, despite the fact that the ball is no longer attached to any part of the train while in the air, it continues to move forward with the same velocity as the train, so that it keeps constantly vertically above the hand, although with respect to the ground outside, it describes a parabola. If you open the window of a moving train, and throw a bottle or something directly at a telegraph pole, the moment it comes opposite, you will not hit the latter. The bottle, preserving the motion of the train which it has, will, except in so far as retarded by the wind, remain directly opposite the window, and, pursuing a diagonal course with respect to the ground, pass in front of the pole. Similarly, the flier, who drops a bomb from his aeroplane, the moment he comes directly over the target, will find that the bomb remains directly under the plane throughout its fall and hits the ground in front of the target, the same distance, or nearly so, that the plane has meanwhile traveled.

Now, the shut-up train, or any similar box, moving with uniform rectilinear speed, constitutes what is called a Galilean system of reference, and this first stage of physical relativity is called the mechanical relativity of uniform motion. It is also called Newtonian or classical relativity. It asserts that by no mechanical experiments, performed in a Galilean system of reference, can the uniform rectilinear motion of that system be detected.

Now, of course, we shall never have the advantage of a perfectly smoothly running train with which to experiment. But in the earth itself we have a superb example of a body moving so silently and evenly that its motion is utterly imperceptible. In fact it was for this reason that its motion was so long unsuspected. Here we are being carried along far faster than any express train, or even than the swiftest projectile, yet totally unaware of the fact. All our work, building, surveying, engineering and even delicate laboratory experiments are done and take place exactly as though the earth were standing still. Hence the earth itself affords an excellent Galilean reference system. Yet it is not quite perfect. Its course is not quite straight. A point on its surface describes a great circle some six thousand miles in diameter in temperate latitudes. By means of the Foucault Pendulum, the gyroscope and a few other delicate methods, this motion can be detected because of its curvature, although the deviation from a straight line is less than a foot per mile. But in its motion around the sun, the earth swings in an orbit 186,000,000 miles in diameter. The deviation from a straight line is here less than four ten-thousandths of an inch per mile, which is a far straighter line than any surveyor could lay out. Hence up to the present no instruments have been constructed sufficiently delicate to detect this motion. From this it appears that mechanical relativity does not apply to non-uniform motion. The latter betrays itself in the altered behavior of our instruments.

The second stage of physical relativity resulted from the Michelson-Morley experiment in 1886. This endeavored by an optical method to detect the motion of the earth with respect to a hypothetical surrounding ether, supposed to be stationary. It has been claimed that this was an attempt to determine the absolute motion of the earth through space. It was nothing of the sort. Motion with reference to the ether is still relative motion. The universe as a whole, as has already been pointed out, constitutes a Eulerian body, whose motion through space would constitute absolute motion. But the motions of the various parts within that system with respect to some one part are relative. That the system as a whole might be moving in some unknown and unknowable fashion is no concern of the physicist, for he is perforce confined to what he *can* know. Nor does the failure of the Michelson-Morley experiment constitute empirical proof of the non-existence or unknowability of absolute motion. No empirical proof of these things can be given.

There is, however, a sense in which the physicist uses the word absolute which is different from the philosophical usage. Thus the physicist has the absolute and gravitational systems of measurement. The latter depend upon the unit of weight which varies from place to place. The former depend upon the unit of mass which is the same everywhere. So, also, he has absolute temperatures, measures, constants, etc. He simply means, more universal, less relative to particular or local things. His absolute is only relatively absolute, not absolutely absolute, like that of the philosopher. Hence he has degrees of absoluteness, which the philosopher has not. His highest degree is that which is the same for all observers however conditioned, *i.e.*, the universal empirical.

Now, if the stars are embedded in an all-pervading ether which is not affected by their relative motions, that would form an excellent reference frame to which to refer all motions. Such motions would be the same for all observers, however situated. They would, therefore, be absolute in the physicist's sense, but not in the philosopher's. The existence of these two uses of the word absolute has doubtless caused confusion.

The failure of the Michelson-Morley experiment showed that no such universal reference frame exists. Therefore, neither by mechanical nor by optical, or more generally by electro-magnetic, means can one detect the uniform rectilinear motion of the system in which he is situated. This is Einstein's "Special Theory of Relativity," 1905. It may also be called the complete relativity of uniform motion. It is, of course, supported also by other experiments.

Having thus established the complete relativity of uniform motion, it was natural that Einstein should advance to the consideration of non-uniform motion. This was conquered in 1915 by his "General Theory." Unlike the other two stages of physical relativity, this third stage was not an after-interpretation of experiments originally performed for quite other purposes, but resulted from first assuming the hypothesis, then seeking what modifications must be made in our physical ideas to conform with it, then devising experiments to test the assumption. As far as mechanical matters are concerned, he found that we already possessed what we needed, only it must be a little differently formulated. This he did in his principle of equivalence.

Let us go back to our smoothly running train. But instead of moving uniformly, let us suppose that the velocity is constantly increasing, everything else, however, being as smooth and silent as before. What will now be the experiences of the inmates? First of all, they will observe that there is a sort of drag upon everything toward one end of the car. A ball placed upon the floor will roll down toward this end with increasing velocity. A man standing in the aisle will have to lean toward the other end to maintain his balance. He will find it more difficult to walk toward this end than toward the other. The surfaces of liquids will stand at an angle to the floor. The plumb line will be similarly inclined. What will be the conclusion of these people with regard to their situation? Naturally they will conclude that their abode is resting on the earth in an uptilted position. And no experiment that they can perform will contradict this conclusion. Of course, some Copernicus might finally arise among them, and point out that the phenomena are equally consistent with the idea that their abode is moving in the direction of what appears to be the high end, with a uniformly increasing velocity. But he would probably be considered a crank. And his curious hypothesis could never be tested until some Galileo thought to bore a hole through a side wall and look outside.

In the same way, Einstein has shown that all the mechanical phenomena that we have been accustomed to associate with changes of motion can be equally well accounted for, and actually produced by the application of suitable forces and *vice versa.* Their indications are ambiguous. They can be accounted for in two ways. And these two ways are equivalent, that is, one is just as good as the other. And the only way to decide between the two is to observe bodies outside the system. Particularly illuminating is his discussion of rotary motion—the case that puzzled Newton and many others since. The existence of centrifugal forces does not necessarily imply rotation. They may be actual forces produced otherwise. We know, of course, that a plastic sphere when rotated will become flattened at the poles. But the mere existence of a flattened sphere does not inevitably mean that it acquired its shape by rotation—some one might have hit it with a hammer. In virtue of this principle of equivalence we therefore already have mechanical relativity of non-uniform motion.

But how about optical and electrical phenomena? Here it was found that if the ordinary conceptions of the nature of radiant energy were true, one would have an infallible means of distinguishing between a field of force and a change of motion. The principle of equivalence would no longer hold. But if light had mass, momentum and weight, and in all other ways acted like a stream of material particles, then this would not be the case. We should then have complete relativity of all motion, both uniform and variable. The eclipse and the spectrum experiments decided in Einstein's favor.

In all this it makes not a particle of difference whether any of the motions concerned are absolute, in the philosophical sense, or not. Physical relativity does not depend on, nor is it a product of, philosophical relativity. It is something entirely new, discovered by experiment, unforeseen and unforeseeable by any philosopher. It stands on its own feet. And so long as the experiments on which it depends continue to support it, it will continue to stand. But if these should fail, it would have to be abandoned, and not all the philosophy in the world could save it. Likewise, philosophical relativity, the relativity of all knowable motion, stands on *its* own feet, on its own theoretical grounds. And it will continue so to stand, though all Einstein should fail.

ENTOMOLOGY IN RELATION TO INDUSTRY

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WHEN one speaks to-day of the science of entomology it is natural, especially for the scientist, to think first of the pure science, insects as animals, and consequently of the zoological connection rather than of the economic or applied phases. It is true of course that entomology had its origin in this way and for many years continued to be a strictly zoological science, but as entomology has gradually developed, by the very nature of the human and economic relationships involved, it has become more intimately associated with the economic and industrial problems of the world in which we find ourselves.

From the time that Dr. Harris, who has been termed the father of economic entomology in America, published his treatise upon injurious insects in 1841 to the present day, the development in this field of applied science has been remarkable. The greater part of this development, too, has taken place during the last thirty to thirty-five years. The problems have become more diversified and complicated and the interrelation of entomology to the fundamental and agricultural sciences has become more pronounced. This rapid development has been brought about chiefly by the applied phases of the subject and their application to the problems of life and industry, until at the present time the scope of the field has become so broadened that it touches and affects many phases of industry. The scientist who has not been working directly in the field is probably not aware of the vast numbers of different industries affected by insect problems, but when one begins to look about him to find those that are affected to more or less degree, the surprising thing is to find how few have escaped either slight or serious losses or have failed to be affected.

If we discuss rather briefly the various industries affected, we should probably mention first those directly concerned since their raw material is manufactured by the insect either as a direct product or in its attempt to pass certain life stages. Chief among these industries are, first, the manufacture and commerce in silk, dealing with all phases of this problem from the actual feeding and rearing of the worms to the weaving and selling of cloth. When we realize that 45,000,000 pounds of silk are produced annually with a value of approximately $200,000,000, we can estimate the numbers of individuals employed in these various processes. Second in importance is the manufacture of honey and wax by the bee. The honey crop in the United States is valued at something over $20,000,000 and the wax is valued at $4,000,000 annually. This has become an important commercial phase of insect work. Two other industries which might be included under this type and which would probably rank third and fourth, respectively, are those manufacturing shellac and cochineal dyes. Insects are responsible for or aid in the manufacture of both of these products.

In addition to those industries which deal chiefly with manufactured products of or by insects, the next great industry which is most seriously affected is that of agriculture. It is neither necessary nor advisable to discuss this subject at length at the present time, but simply to state the problem in a very brief manner by saying that the farmer's task is to grow at a profit plants and animals to feed and clothe the peoples of the world. In doing so he is confronted with insect problems on every hand, these pests destroying his crops and parasitizing his animals. No plant or animal has yet been found which is absolutely free from the attacks of insects, and the average toll of all these products taken by insects is approximately 10 per cent. The loss to agriculture is enormous, being conservatively estimated at $2,000,000,000 annually. One of the most striking evidences of this loss is the recent $10,000,000 corn-borer appropriation, as well as the large sums appropriated annually for Japanese beetle, gipsy moth, Oriental fruit moth and similar problems.

We might consider briefly several of the industries which are outgrowths of the farm or whose business is built upon the manufacture or handling of farm products. All animal industries are of such a nature. Insect parasites attacking cattle affect our sources of meat supply by reducing the vitality of the animal and by actual destruction of the muscle in the case of parasites like the warble fly. In like manner the amount and quality of milk production is reduced, so that dairies and creameries are required to face the insect problem in regard to their supply as well as the possibility of insect infestation or contamination of their retail product.

All the leather and leather products industries are affected by insect parasites that puncture and eat holes in the hides. Where this occurs, scar tissue is formed which renders this portion of the hide worthless so that the value is greatly reduced. This is one of the most striking losses in the cattle industry at the present time.

The meat packing industries are affected by the insect problem in at least two ways: the attacks during the animal's life, and more especially the meat products after the animal is slaughtered. The soap manufacturing industries and all similar types where animal fats or oils are used in manufacturing various products are similarly affected. The fur industries suffer severe insect attacks. The external parasites of course are important in this respect during the life of the animal, causing diseases like mange and scabies, which destroy the animal's fine glossy coat. But the problem which causes most severe economic loss probably is the destruction of furs after they have been made into coats and other articles of clothing. Since this industry involves a considerable amount of wealth, and has been increasing rapidly and for the most part among a class of people who have no appreciation of the insect problem, the losses are enormous. The clothes moth alone, for instance, causes something like a million dollars of damage annually in Ohio. We must not forget either the total loss of life among animals due to insects transmitting bacterial or protozoan diseases from animal to animal and where in many cases the insect is the important factor since it is the only vector.

In discussing rather briefly the animal industries, cattle have been cited as an example, but all domestic animals on the farm, horses, sheep, hogs, etc., are similarly affected with various parasites and could be discussed at length in the same way. The poultry industry producing our supply of fresh eggs and the fowls for market is similarly affected by insect parasites, especially external types.

We might turn for a moment to glance at other industries handling agricultural products which are greatly affected by insect pests. All the canning factories should be mentioned in this capacity.

Vegetables of all types, small and tree fruits and similar products are handled by these factories. The canned goods industry, too, has become enormous since it provides so much of our daily food supply. To mention a specific example, in 1925 one canning factory in Essex County, Canada, where the corn borer has caused severe losses, was obliged to spend $250 a day for extra labor alone during the corn canning season, in view of the fact that certain types of machinery could not be used for corn infested with this pest. In the same manner we might mention, if time permitted, the losses to all types of vegetables and fruits caused by insects. In many localities and during various seasons aphids or other pests may cause the loss of entire fields of peas, beans, spinach, celery or other crops. The fruit losses due to insects are enormous, especially in view of some of our most recent importations like the Oriental fruit moth and Japanese beetle. All the pickling and preserving industries can be included in the same type of problem so far as insect losses are concerned.

The dried fruit industries and canned dried fruits have presented some puzzling problems of control. Dates and figs, apricots, peaches, apples, prunes, etc., suffer losses both during the growing season and storage. Fruits coming from Mesopotamia on grain freighters are seriously infested when they arrive and treatment is difficult. The storage problem is therefore becoming more serious in many cases.

The industries manufacturing grape juices and other fruit juices and fruit extracts, and the flavoring extract industries must consider the insect problems. We find that the insect infestations reduce markedly the sugar content of fruits and as a consequence the quality of the product is inferior and the value is greatly reduced. Fruit of this kind is often refused by these industrial plants even under a contract price.

The baking industries are affected directly in one way, due to the insects which attack wheat in the field or storage. In another way they are affected by insects infesting figs and other fruits. In the process of making fig newtons, for instance, the law no longer requires an insect-free product but states that the infestation of stored products insects must be below a certain percentage since it is practically impossible to keep them insect-free.

The English walnut, pecan and other nut industries are severely affected by nut weevils, case bearers and similar pests. All the sugar industries and those where sugar is used in manufacturing candy and other products must face the insect pests in the form of the sugar-cane insects, the beet leaf hopper, and many other field pests, as well as stored products insects common in candy and similar products.

Many industries are affected by the stored grain insects which belong to several groups. All granaries, flour and grain mills, grain elevators, cereal packing houses, warehouses, seed stores and even grain freighters on our high seas and all the industries handling these products have been brought face to face with the insect problems and have had to devise means and apparatus for intermittent control measures in these plants. To the average biologist it seems practically inconceivable that a small insect could become so abundant and such a pest as to clog the machinery of a mill and necessitate the closing of operations for a short period to eradicate these insects. But such has been our experience with several of the silk-spinning type of larvae and many of us have observed these conditions. These losses and costs due to destroyed products, loss of operating time, additional apparatus and construction in anticipation of insect attacks are enormous.

The tobacco industry suffers serious losses by insect pests, both in the field and storage. In spite of the fact that this plant is the source of one of our most toxic plant poisons, certain insects seem to be able to consume it and to thrive upon it. The paper and paper board manufacturing concerns where straw and wood pulp are used as raw products must consider losses by field insects and wood borers of several types.

The building industries are affected probably most seriously by the termite problem. The architect must plan to use different materials in construction so as to counteract these attacks. In the modern home the wood work, the sills, hardwood floors and even the furniture are common objects of attacks, causing annual losses. Even fireproof buildings contain termite colonies in the small pieces of wood used to finish the interior. The cost of timber for all types of building construction has increased, and lumber is graded largely according to the amount of insect damage present. The wood boring insects are especially destructive to growing timber and this problem alone is causing much concern for the timber of the future. All the lumber and building industries must face the insect problem, both in the case of growing timber and after it is stored in the lumber yard, not to mention the houses that are constantly crumbling to pieces because the insects have destroyed the foundations. In addition we might mention the coal tar products industries and wood-preserving devices which are now being used.

Another enormous industry, the furniture business, is finding itself rapidly facing more and serious insect problems. The materials used in its manufacture must be more carefully selected because of these injuries, but the real problem is the protecting of upholstered and overstuffed furniture against the attacks of moths and similar pests of fabrics. Mohair cloth is especially susceptible to their attacks and by the very nature of the weave expensive furniture is frequently ruined before injury is noticed. This leads to the installation of heating chambers and similar devices to protect these articles of furniture, and adds a new industry which has been brought about by this demand for the control of an insect pest which has caused so much loss in the commercial world. The piano industry suffers losses by destruction of the felt pads and similar materials within these musical instruments requiring rebuilding and enormous losses in many cases. The carpet and rug manufacturing concerns suffer similar attacks and severe losses since slight injury reduces the value greatly. In like manner all the industries dealing with plant or animal fibers, such as cotton, hemp, wool or mohair, which are stored either before or after woven into cloth, must constantly consider the problems of the insect pest either in the growing stage of the plant or animal in the field or after these have been made into fabrics.

Many phases of the work of the tree surgeon and the landscape gardener are directed solely at insect attacks or are the result of previous insect infestations. When attempting to beautify the home surroundings or the estate the constant fight upon the insect must be kept in mind. The greenhouse industry, which is becoming a very important one, where cut flowers, winter vegetables and similar luxuries and necessities are raised, is one of the most difficult to accomplish since the conditions under glass favor rapid and abundant development of pests.

We might turn for a moment to glance at industries which seem so far removed in many cases from the insect problems that one would consider the insect a negligible factor. Certain engineering

projects might be placed in this group. Yet the very nature of engineering work takes the operators, surveyors and supervisors as well as many workmen into the most dangerous places as far as disease dissemination is concerned. Mosquito control itself is partially an engineering project. While considering this phase of the work, we must not forget that the Panama Canal stands as a monument to the success of a project of insect control. That it was built only after the mosquitoes had been controlled and all the engineering skill the world could produce was held at bay until that insect problem was solved.

The real estate business hinges in many cases upon this same problem. Land values are usually very low where mosquitoes or other similar insects are present in sufficient numbers to make normal living conditions almost impossible. When the insect is controlled, the real estate values immediately rise enormously. Many of our low marshy seacoastal areas in the United States have been of this type. One of the most striking examples of what can be done is that of converting Miami Beach, Florida, from a mangrove swamp to a large area of fine estates and beautiful mansions. The engineer has seemingly been responsible for this, but the incidental control of the insect problem and the consequent control of malaria and yellow fever has been the secret to the choice of these areas for homes and the subsequent rise of these real estate values.

It would seem that those industries which are concerned with various metal products and their use in a commercial way are entirely removed from insect questions, but investigation shows that even these in some cases are affected. The clogging of mill machinery by silk-spinning caterpillars during their migration before pupation has already been mentioned. We have on record a few cases where even the iron horse of commerce has been halted in its rapid course because of insects swarming or of gregarious migrations. And now comes the lead cable borer of the Pacific coast which deliberately bores into lead cables containing electric wires short-circuiting these and causing the companies involved decided losses.

Undoubtedly the insect problems that come closest home to all of us are those concerned with health and sanitation. All foods are dangerous as sources of insect contamination since they may contain insect larvae which cause myasis in man or may contain disease organisms transmitted to these foods by insect vectors. Restaurants, hotels, food shops of all types, and even the home may be places where the insect problem is an important one to life and health. As a specific example, I might cite for you an experience of a few years ago when I was privileged incidentally to enter a dark, gloomy, artificially-lighted basement kitchen of a large restaurant in one of our eastern cities and found the cockroaches perfectly at home and crawling about in great numbers, leisurely walking in and out of the roast chickens lying upon the meat block, not to mention other articles of food which were constantly being contaminated and which would later be taken to the tables above in an attempt to satisfy waiting appetites. The entire kitchen presented the same appearance of extreme carelessness in regard to sanitation.

The household also contains pests that injure fabrics of all types from the carpets and rugs on the floor to the woolens which are stored away until the following season. These affect decidedly the home life of man. The physicians must treat diseases that are partially or entirely insect-borne such as typhoid, dysentery, enteritis, anthrax, malaria and yellow fevers.

I have mentioned several of the wide variety of industries or professions affected by insect pests more or less directly in their relation to raw materials or finished products. If we consider those industries affected when we attempt to devise and use control measures for these pests, we must mention many others which we have not previously considered.

Probably the largest group of industries thus affected are the chemical companies which manufacture arsenicals of various types, lime and sulphur products, copper sulphate, fluorides and fluosilicates, plant products such as pyrethrum, derris, nicotine and their extracts, soaps, oils, both vegetable and petroleum, as well as acids and salts of various kinds which are used as chemical controls for many types of insects. Also the spraying and dusting machinery manufacturing concerns should be mentioned whose business is built entirely upon the presence of insects or other pests in sufficient abundance to cause economic damage.

More recently it has been necessary to manufacture special machinery like the aphid-dozer for the pea aphid, the stubble beater, corn-cutting machines and special types of cultivators for the corn borer, and attempts have been made to manufacture and use electrical machinery, complicated and expensive mechanisms in some cases for the control of stored products insects. The cold storage industry is now becoming a special device for insect control.

This brief résumé may bring to some who have not given it thoughtful consideration the importance of the insect problem as related to industry. In view of these problems more industrial companies are realizing their need of trained entomologists and there is a greater demand for men who are able to handle these problems. The insecticide concerns and oil companies are employing trained entomologists to fill research positions and carry on field experimentation. The canning factories and furniture dealers are also employing trained men for specific insect control duties. Super-heating and cold storage plants costing a hundred thousand dollars or more in many cases are being installed for problems of insect control alone. The economic entomologist to-day may find his work varying from the pure science, on the one hand, to the applied and strictly industrial phases, on the other. It can therefore be clearly seen how the applied phases of entomology and research along these lines have helped and are helping to solve many of the important problems of industry. Thus entomology is rendering a biological service through these applied phases which is not surpassed by other biological sciences.

FISHERY PRODUCTS IN THE ARTS AND INDUSTRIES[1]

By LEWIS RADCLIFFE

U. S. BUREAU OF FISHERIES

OUR thoughts of fish and fisheries are usually in terms of food and sport. We are prone to forget that from prehistoric times to the present fishery products have served many other and varied uses. Amber, corals, pearls and shells of many kinds were used by ancient man for barter. Wampum, consisting of beads made from shells, was used by the North American Indians as money, ceremonial pledges and ornaments. The Egyptians and the Assyrians derived dyes from certain species of molluscs. The royal purple of the period of the Roman Empire was so gotten, factories being scattered throughout Italy and Greece. Sepia also was obtained from the ink sac of another mollusc. The teeth of porpoises and sharks, like wampum, have served as a medium of exchange in some of the islands of the Pacific.

Many products which at one period seemed highly essential in satisfying human needs have been replaced by more modern inventions and discoveries. With the development of the Argand burner in 1784 whale oil became the principal illuminant for homes, streets, lighthouses, etc. Formerly whalebone was extensively used in making ribs for umbrellas and parasols, in the manufacture of hoops in the dresses our grandmothers wore, and as corset stays in the days when our mothers were young. Shark skins as abrasives for polishing wood, ivory and the like have been replaced by emery and sandpapers. With the exception of choice pearls and corals, ambergris was at one time the highest priced product of the fisheries, selling for upwards of $640 per pound, the take from the intestine of a single whale selling for as high as $60,000. The principal use was as a fixative in the preparation of fine perfumes. As synthetic substances have become available at a fraction of the cost, the use of ambergris in recent years has greatly decreased, until it has sold as low as $128 per pound.

While many fishery products have dropped within the limbo of the forgotten past, the number of such products catering to our needs and vanity to-day are greater than at any time in the history of the world. Figuratively speaking, the modern flapper might dive into the sea and emerge completely clothed and adorned with aquatic products, such as to be the envy of any mermaid of the briny deep. She will be wearing a dress of artificial silk made from the shells of crabs, lobsters, or other crustaceans; a fur coat of otter, sealskin or beaver, with mink or muskrat trimmings; shoes of shark-skin and mussel shell buckles adorn her feet; the buttons on her dress are of pearl derived from fresh-water mussels and those on the coat of true pearl, abalone or artificial pearl. She wears a string of natural pearls on special occasions, and a duplicate set of imitation pearls for ordinary use. Coral earrings and a tortoise shell comb complete her outfit. In her alligator leather handbag she carries a cake of soap made from fish oil; cold cream from whale oil; a sponge; a bottle of perfume with ambergris as the fixative, a hand-lotion made from sea-

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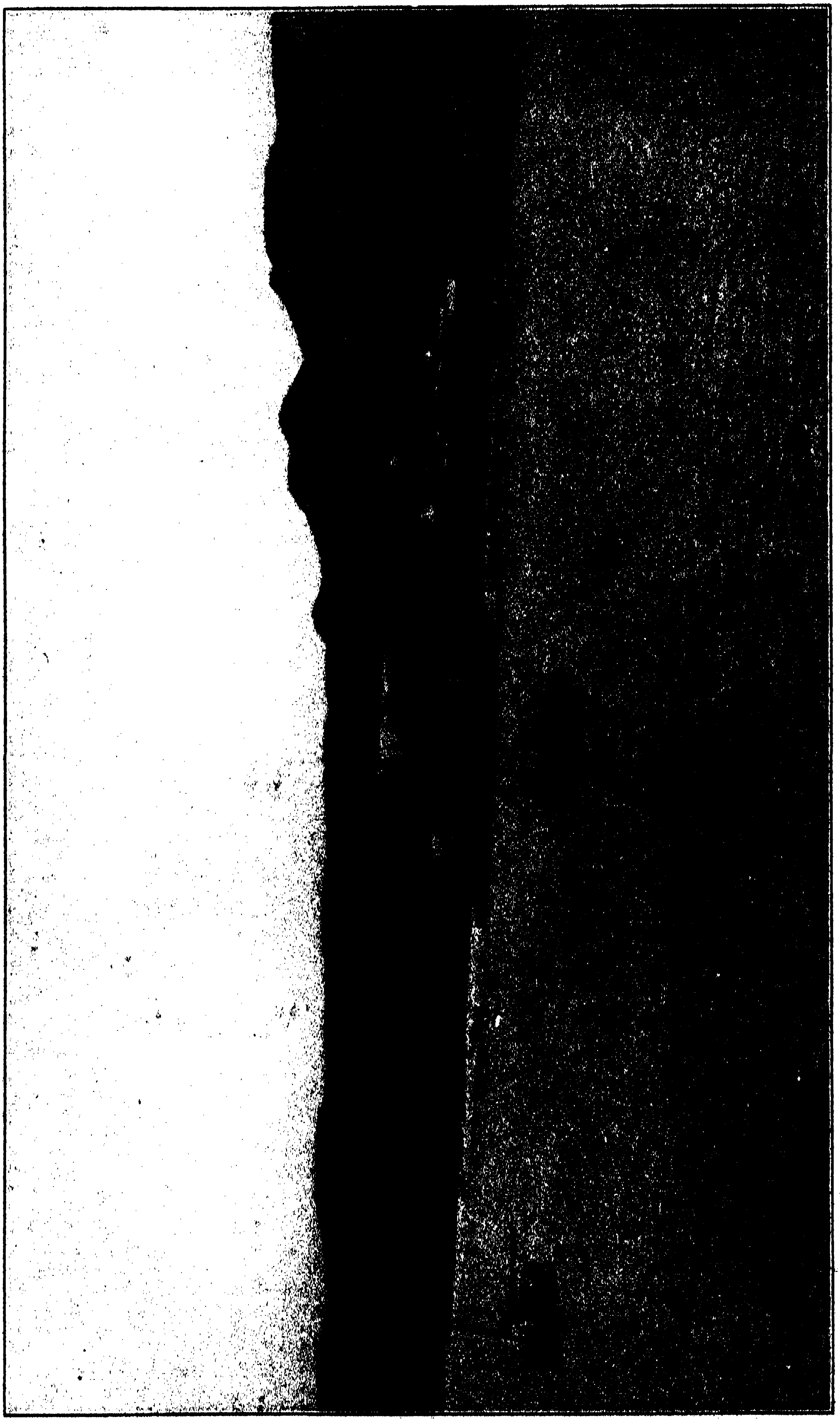
[1] One of the Smithsonian series of radio talks arranged by Mr. Austin H. Clark and given from Station WRC, Washington.



LA PAZ, LOWER CALIFORNIA
TAKEN IN 1889.

A MUSSEL BARGE
EQUIPPED WITH CROW-FOOT HOOKS; VEVAY, INDIANA, 1913.

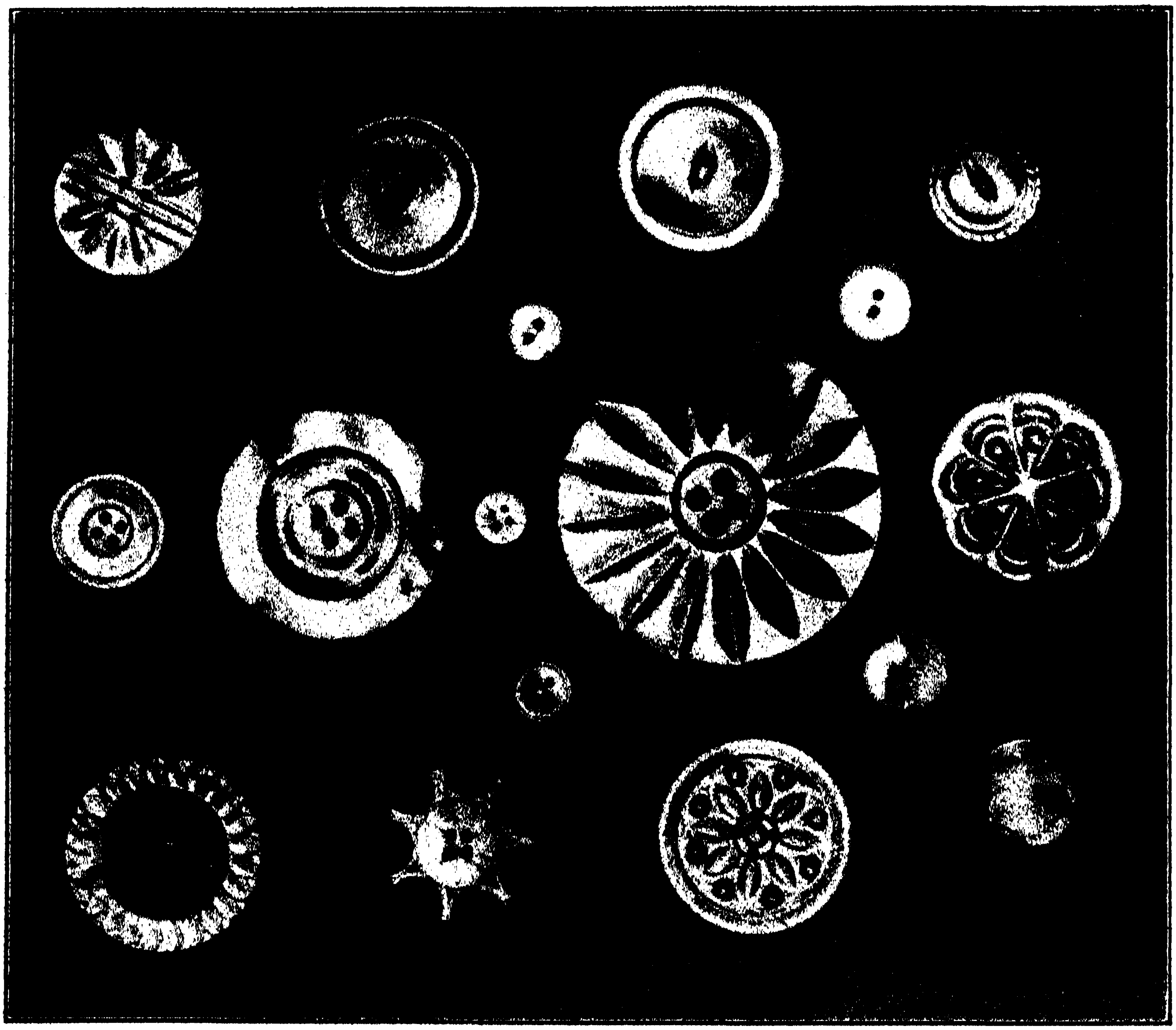
moss, and gloves of cod skin. On her way home she views a photogravure which was covered with fish glue before etching and purchases a beaver hat adorned with an aigrette made from whalebone; a toilet set trimmed with artificial pearl made from fish-scale essence; am amber pipe for her husband; a bottle of cod-liver oil and a package of agar agar for gelatin for the youngsters, and a piece of cuttle-fish-bone for the canary.

Pearls have been described as "Heaven-born and cradled in the deep blue sea; it is the purest of gems and the most precious."

Pearls were the earliest gems known to prehistoric man and throughout the centuries have continued to be prized most highly. So highly valued are they that it is most natural that man should strive to grow them and to produce imitations of true pearls. As a result we have three classes of pearls: Genuine pearls, *i.e.*, those produced in nature by pearl-bearing molluscs; artificial or culture pearls, *i.e.*, those produced by molluscs, as a result of artificial stimulation by man, such as the insertion of foreign objects into the mantle of the mollusc; and imitation pearls, *i.e.*, products made to resemble pearls.

In North America genuine pearls are found in the pearl oysters of the Gulf of California; the abalone of California and Lower California; the queen-conch of the Gulf of Mexico; and the fresh-water mussels of the Mississippi River system. These fisheries are now relatively unimportant. The production of culture pearls is confined to Japan, where the annual output has been valued at $600,000.

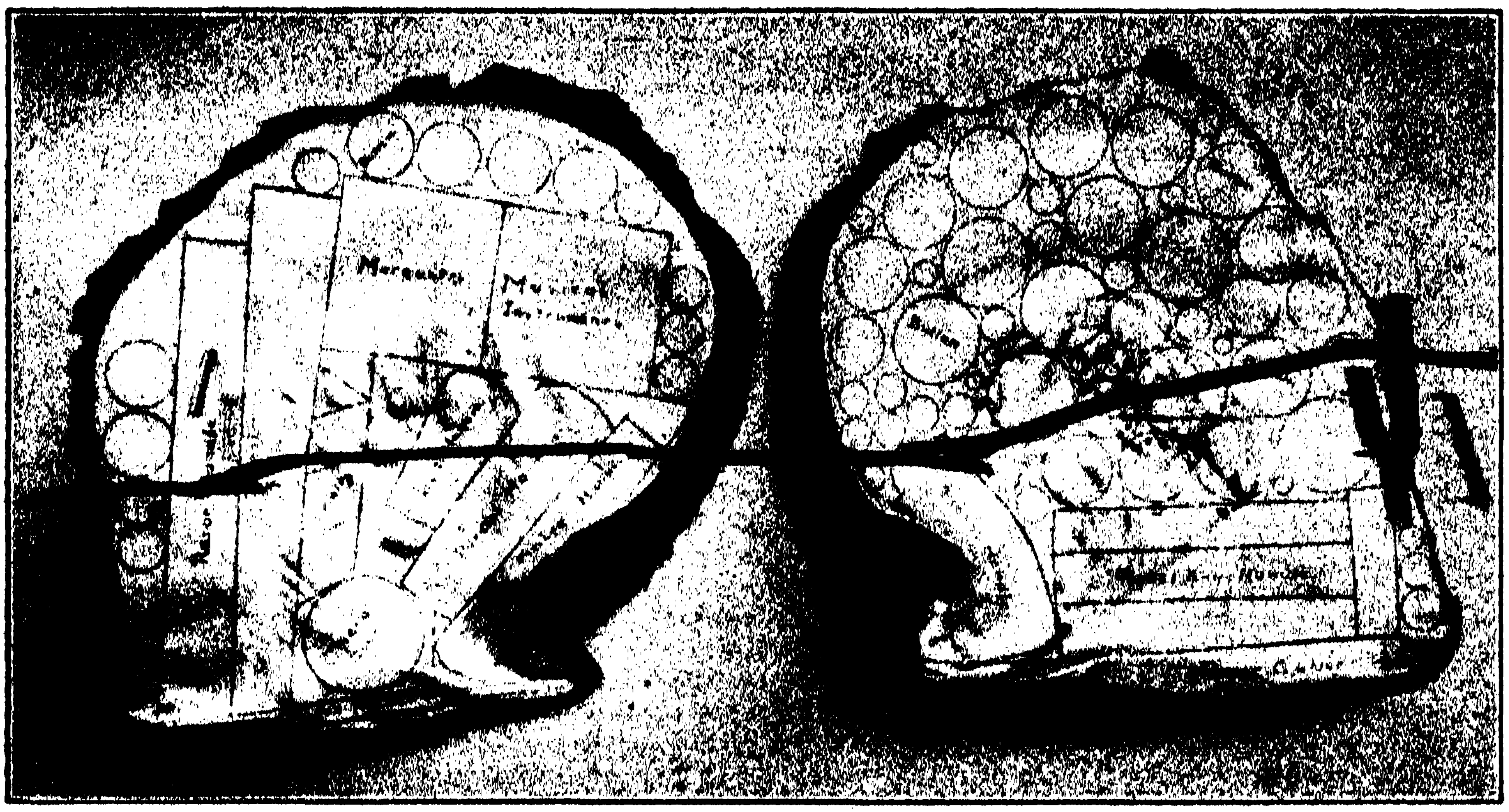
About 1656 Jaquin, a French rosary maker, noted that the water in which a small minnow had been washed contained a highly lustrous substance, which when concentrated closely resembled



SAMPLES OF BUTTONS MADE FROM THE BLACK MOTHER-OF-PEARL SHELL

pearl. Applying it to small globes of alabaster, Jaquin produced for the first time excellent imitations of pearls. The crystals which give this lustrous effect are found on the scales of fishes. From the seventeenth century the European minnow which Jaquin used continued to be the chief source of supply of pearl essence or fish-scale essence, and became the basis for a very large industry. During the World War, the European supply was cut off and research with other fishes, coupled with improved methods, resulted in the developing of new sources of supply in this country and the building up of a new and important industry. This new source of supply is obtained chiefly from the sea herring of New England. At the present time, two million pounds of fish scales are used annually, for which our fishermen receive about $140,000. In addition to the manufacture of imitation pearls, the essence is employed in the manufacture of imitation mother-of-pearl celluloid products, which, in turn, are used on backs of brushes, hand-mirrors and other toilet articles, for umbrella handles, buttons, etc. In a decade this domestic production of pearl essence has become sufficiently large to attract foreign buyers, and the manufactured products now are to be found even in the "Five and Ten" stores.

Formerly the fresh-water mussel fishery was prosecuted primarily for the

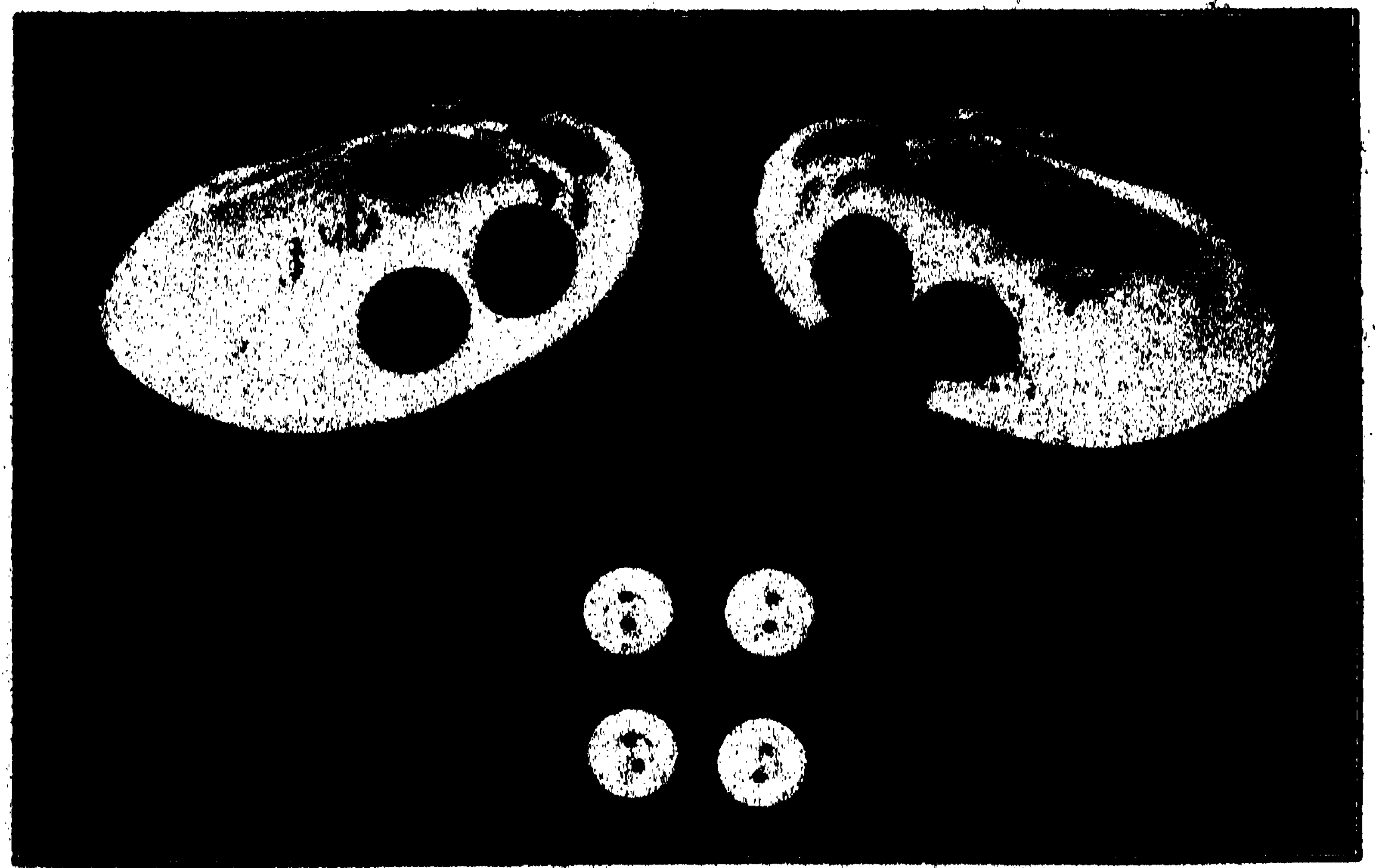


A BLACK MOTHER-OF-PEARL SHELL

SHOWING HOW IT IS CUT UP FOR THE MANUFACTURE OF VARIOUS OBJECTS.

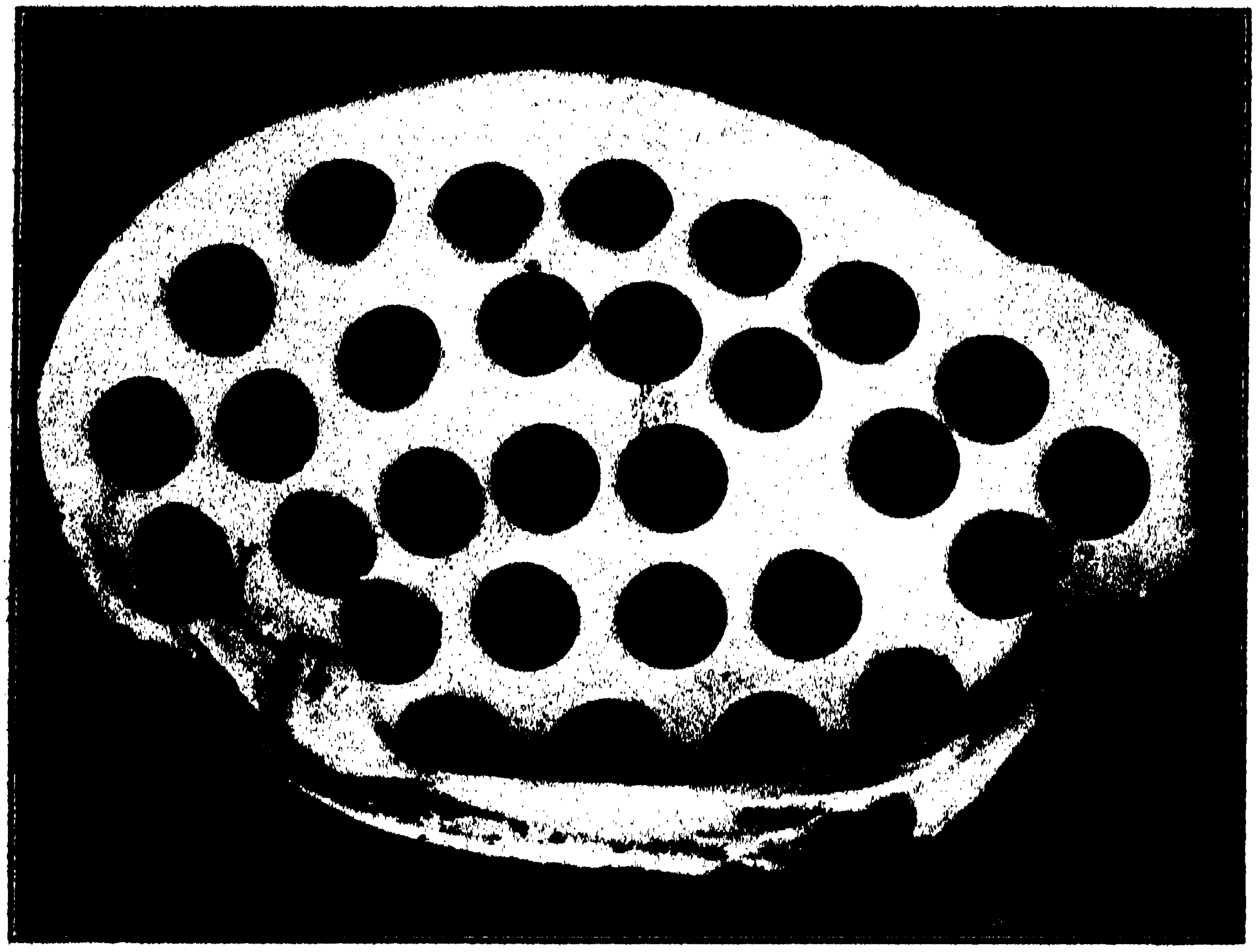
taking of pearls. To-day it is the chief source of pearl buttons, producing over three billion buttons per year or twenty-seven buttons for every inhabitant of the United States. Add to this five additional pearl buttons per capita of domestic manufacture from marine shells.

In 1621, Squanto, the friendly Indian, gave corn to the white settlers of Plymouth and taught them the use of menhaden as a fertilizer. After three hundred years, huge quantities of menhaden are still used for manufacture into scrap for fertilizer, or fish meal, as an animal feed, and the oil extracted for use in paints, soap-making, in the manufacture



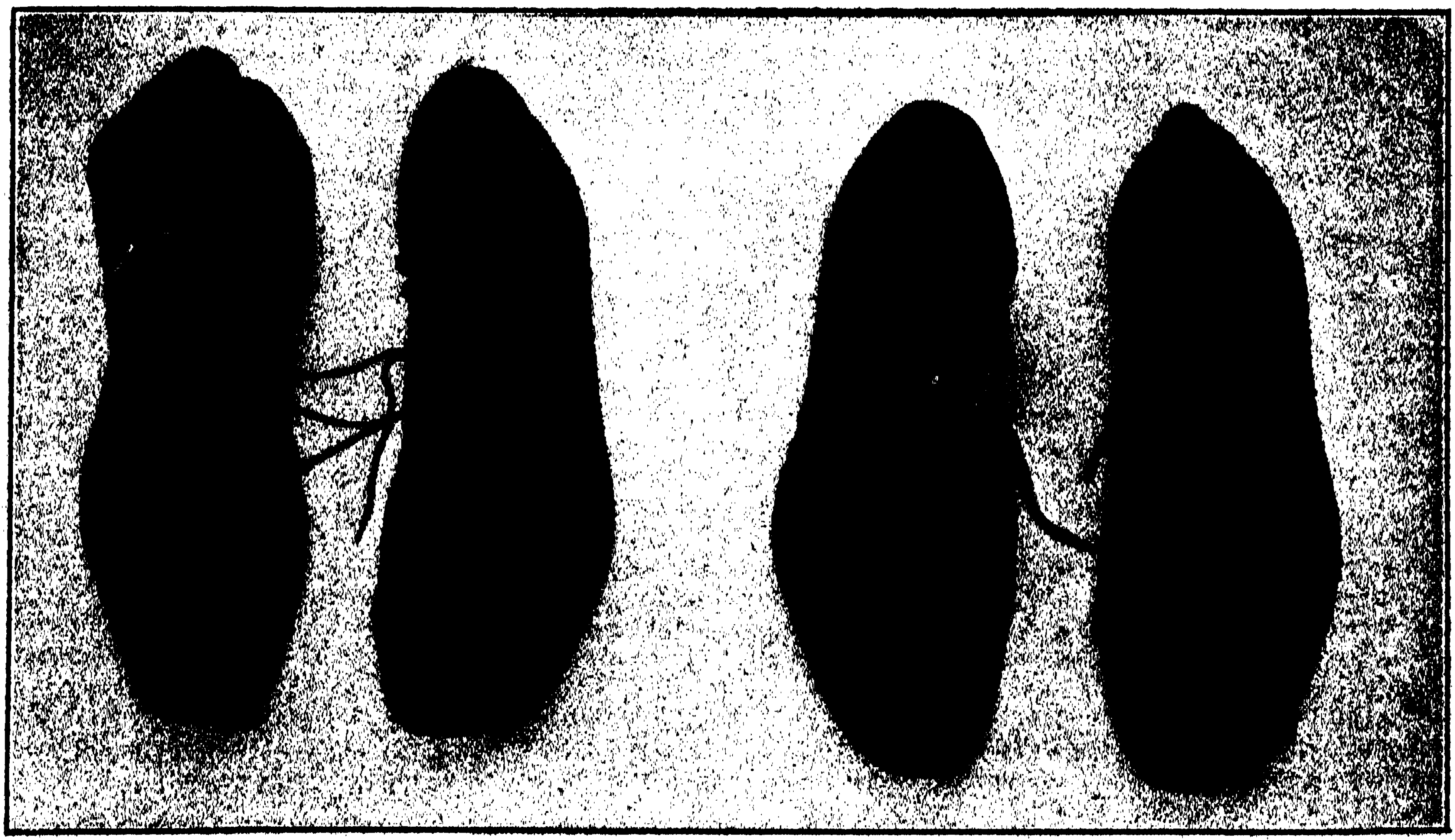
MUSSELS REARED IN PONDS AND BUTTONS CUT FROM THE SHELLS

TWO YEARS FROM DATE OF INFECTION; FAIRPORT, IOWA, DECEMBER, 1915.



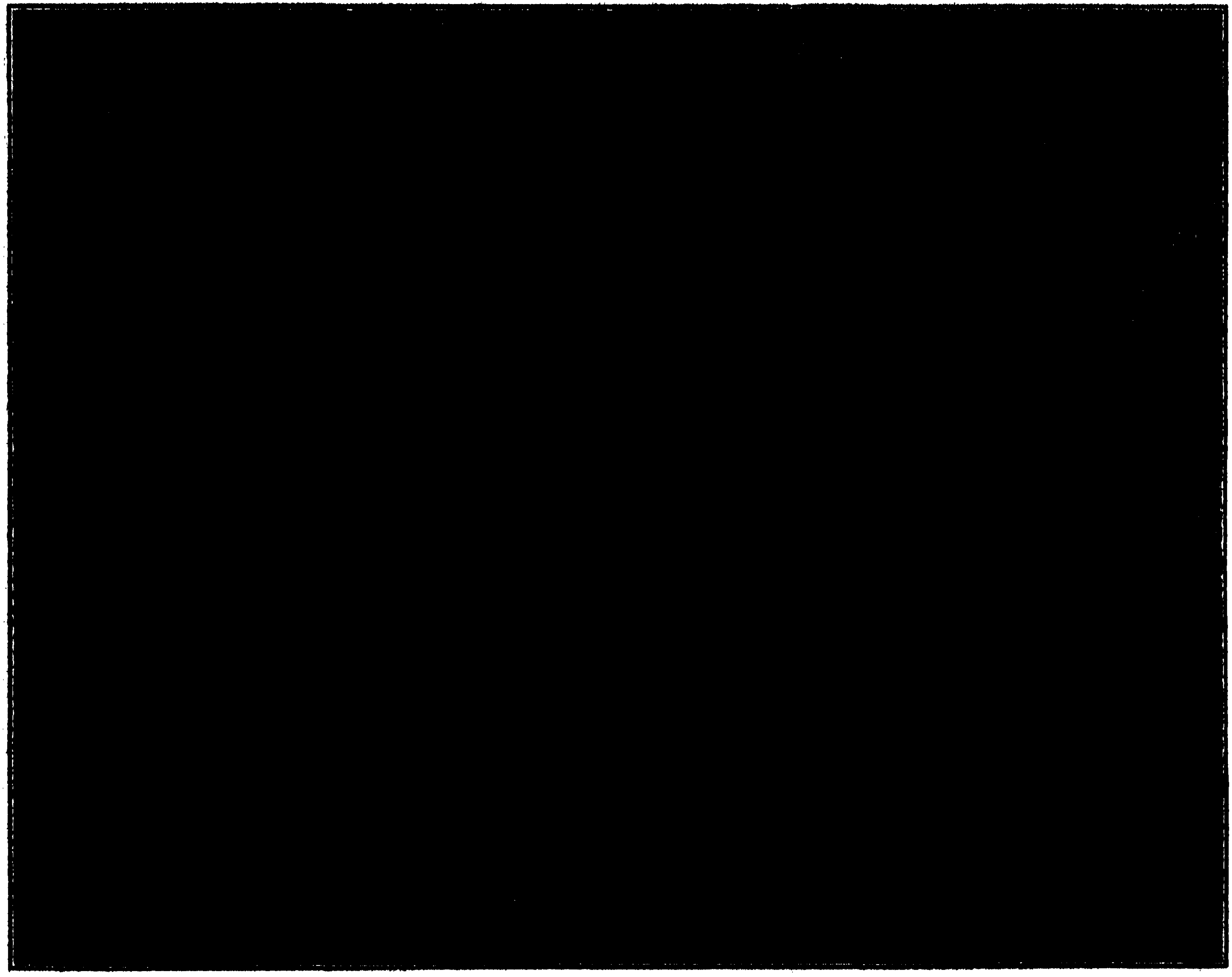
A "WASH-BOARD" SHELL

(*Quadrula heros*) 4⅝ BY 6½ INCHES; FIVE DOZEN BUTTONS WERE CUT FROM THE ENTIRE SHELL.



WORN SHOES OF SHARK AND CALF LEATHER

THE CALF LEATHER SHOES ARE SHOWN TO BE SCUFFED, WHILE THOSE MADE OF SHARK LEATHER HAVE NOT BEEN MATERIALLY INJURED BY ABRASION.



SHARK LEATHER

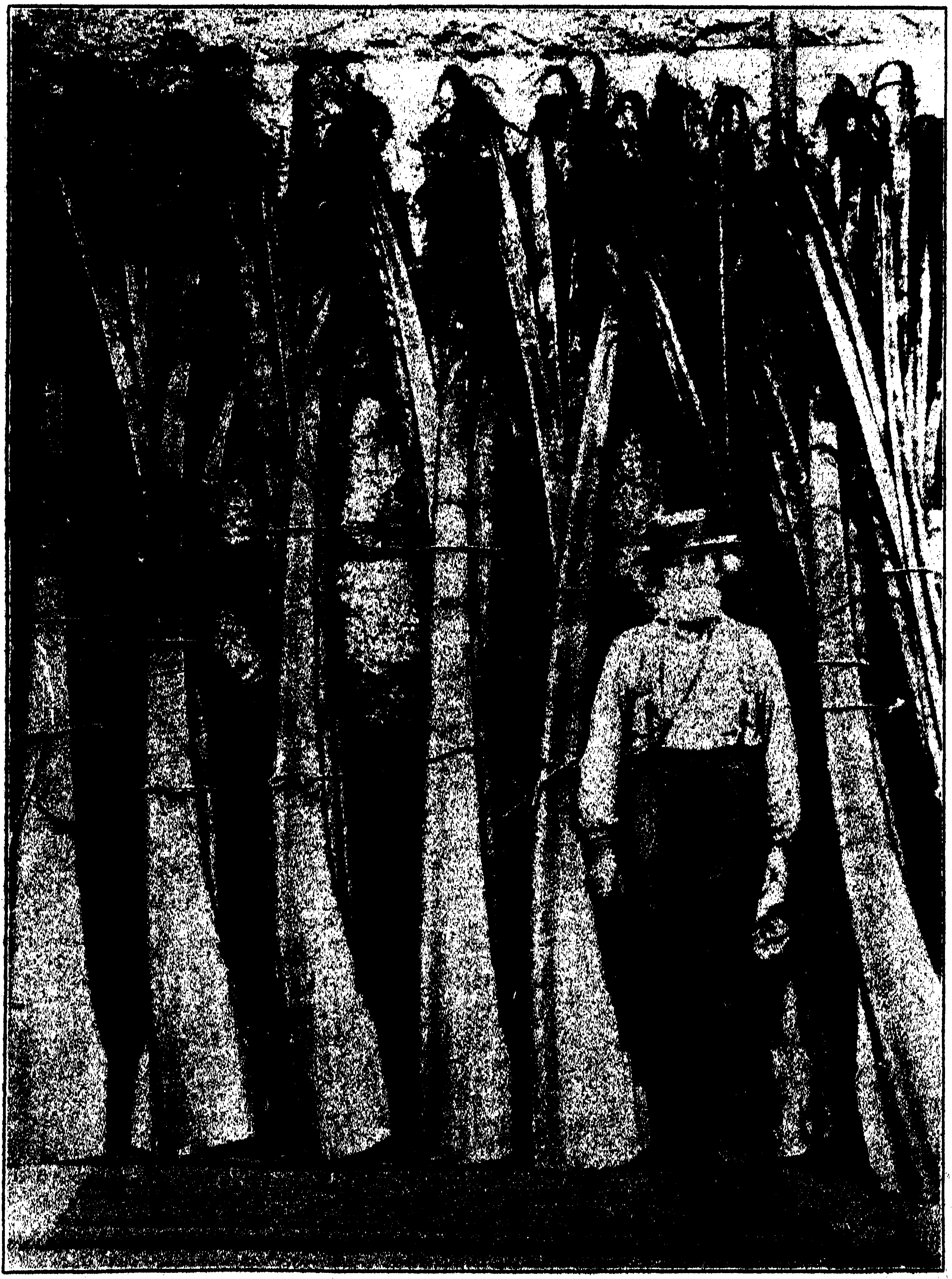
SHOWING THE CHARACTERISTIC GRAIN PATTERN OBTAINABLE.

and stuffing of leather, and for many other purposes. We now produce about 13,000,000 gallons of fish oil valued at $6,500,000 and 120,000 tons of fish meal and scrap, valued at $4,600,000 annually.

Formerly, the oyster packer was confronted with providing some means for disposing of the ever-growing heap of shells. To-day the demand is greater than the fishery can supply and beds of shells of another age are being dredged and carried to the grinders for the making of poultry grit and lime. We produce about 300,000 tons of these products, valued at $2,400,000 yearly.

Agar agar, the dried gelatinous extract of certain seaweeds, is highly important in hospitals and bacteriological laboratories, where it is used as a base for culture media in the study of bacteria and as a valuable dressing for certain types of wounds. In times of war, this country fortunately need not be without an available supply of agar agar, as there is at least one company producing a domestic product of good quality.

From time immemorial the pursuit of whales has been a fascinating and rigorous business. Formerly, only the oil was saved and species like the sperm-whale were most sought for. To-day every scrap of the whale is used—oil, whalebone and scrap or meal being the more important products. The introduction of the harpoon gun and the use of fast boats have added materially to the toll taken of whales yearly. More recently huge floating factories or ships have been



SLABS OF WHALEBONE
IN A WAREHOUSE AT NEW BEDFORD, MASSACHUSETTS, 1902.

SEAWEED ISINGLASS AND SEAWEED GLUE
FROM JAPAN.

built. Some of these are provided with arrangements at the bow, stern or sides of the vessel for hauling these huge mammals aboard for cutting up and reduction, thus obviating the need for shore stations. The fishery is prosecuted with such energy that from ten to twenty thousand whales are being killed annually for reduction purposes, and unless some form of international control is exercised, the supply will soon be commercially exhausted.

Sharks—the wolves of the sea—are now being converted into useful products. Excellent leathers are being made from the hides. The distinctive exterior when tanned makes the leather especially valuable for bags, pocket books and novelty articles, as well as for shoes. The untanned hides of some species are used as abrasives and for sword hilts and grips, as well as nose grips for eyeglasses. Shark fins are an oriental delicacy; oil is extracted from the livers, and the flesh used for fertilizer or feeding purposes.

The skins of many aquatic animals have been used for leather or novelty purposes. Sturgeon, gar-fish, wolf-fish, cod, cusk, water-snakes, frogs and many other forms have been so used. Eel skins have been tanned for book-binding, in making whips, suspenders, etc., or dried and oiled for use as a substitute for glass in windows. Many primitive people use the skins of salmon and cod for making garments, bags and sacks. Bags of alligator hides are in much demand. Hides of seal, sea-lion and walrus are also tanned into leather. The latter is especially useful to silversmiths, gun manufacturers, etc., for removing mars and scratches and for polishing fine metal surfaces. Some of my radio fans may even remember the round leather shoestrings of a former day which were made from porpoise hides. Fish skins, such as cod and haddock, are used in the manufacture of fish glue. Fish sounds or air-bladders are extensively used in the manufacture of isinglass, for clarifying beverages, in adhesives, in sizings to impart a luster and stiffness to linens and silks.

The chief source of supply of the highly prized fur-seals is the Pribilof Islands. Under the wise administration of the Department of Commerce, the herd of fur-seals breeding on the Pribilof Islands has been increased from 140,000 to approximately 800,000 animals in fifteen years, and the annual killings now number over 20,000 animals. As the herds of these animals in other parts of the globe are very small indeed in comparison, were it not for the careful supervision exercised by the Federal Government over the Pribilof Islands herd, fur-seal coats would soon become a far greater luxury than they are to-day. With the upbuilding of this herd, it is hoped to reduce the price of sealskin coats within the reach of many more of our people.

In passing, mention may be made of the recovery of iodine and potassium salts from sea weeds; and common salt and other chlorides from sea water by solar evaporation. In California this is an important industry. Sea water also contains small quantities of gold, silver and radium. Unscrupulous persons have taken advantage of this fact and have sold stock in fake schemes for extracting these valuable elements. The cost of extraction is much greater than the value of the gold recovered, as many investors have found to their sorrow. The history of the products of the sea is replete with fascinating stories—the history of the coral industry, the sponge and pearl fisheries, the seaweed industries of Japan and many others.

STATE GEOLOGICAL SURVEYS

By Dr. HENRY B. KUMMEL

STATE GEOLOGIST OF NEW JERSEY

HISTORICAL SUMMARY

It is nearly one hundred years since the Reverend Edward Hitchcock, of Amherst College, was appointed in 1830 to make a geological survey of Massachusetts, the first of many similar undertakings. In recommending this survey to the legislature, the governor emphasized the fact that by it "much knowledge of the natural history of the country would thus be gained, and especially the presence of valuable ores, with the location and extent of quarries, and of coal and lime formations—objects of inquiry so essential to internal improvements, and the advancement of prosperity—would be discovered and the possession and advantage of them would be given to the public."

Two points in this recommendation and in the subsequent legislation are significant. First, the emphasis is placed on a natural history survey as distinct from a strictly geological survey, and second, the avowed intention of fostering the economic development of the state. The complete report issued in 1833 contained sections dealing with economic, topographic and theoretic phases of geology, as well as lists of plants and animals. It was, therefore, of wider scope than the letter of the governor's recommendations or the legislature's enactment. In these respects this first state survey has on the whole been followed by most of its successors.

As Merrill has pointed out in his admirable history of state surveys the succeeding decade saw them established in eighteen states. So far as I have been able to examine the laws under which they were started, the general plan of the Massachusetts survey was followed; emphasis was placed on the economic advantages which it was expected would result; botanical and zoological studies were included, although the major emphasis was placed on geology, but in their execution they added much to the sum of geologic knowledge in fields other than utilitarian.

In all these early surveys, as indeed in many of the later ones, it was anticipated that the work could be completely accomplished in a few years, generally in three or four. Appropriations were made on that basis and final reports were published. Indeed, it is doubtful if, then or for many years after, it would have been possible to have secured the passage of legislation establishing a permanent or continuing bureau. Even in those states whose existing surveys have had the longest records, as New York, New Jersey and Alabama, the present organization was preceded by one or more earlier surveys, or there were lean years when all state appropriations were withheld, and the work was conserved solely by the personal devotion and interest of the state geologist. In New Jersey the present survey was authorized for a period of four years only; then for five years more, and so for succeeding periods until the adoption of an annual appropriation bill for all state expenditures removed the necessity of special enactments and established the survey as a continuing bureau.

Merrill lists thirty-six states in which surveys had been established previous to 1900, with total expenditures of more than five and a half million dollars, exclusive of a very large but uncomputed sum spent on publication. In 1911 the number of states with surveys, past and present, had increased to forty-four, Idaho, Montana, New Mexico and Utah being the only laggards. It is my impression that they are still in that class.

It is safe to say that the total expenditures by state surveys, during the past century, including cost of publication of reports, which is commonly not included in the direct appropriations, has been in excess of $10,000,000. Large as this sum seems in the aggregate, it is only a little more than $100,000 per year, if distributed over the century. From the standpoint of time, area and natural wealth, it is pitifully small. The profits of a single year in many an industry has more than once exceeded the entire cost of the survey to which it has owed so much.

My excuse for this brief summary of the history of geological surveys is not that it contributes anything new, but that it may form a background to what follows.

Public Expectation

Of all the factors which have to a greater or less extent guided and controlled the work of geologic surveys, public sentiment or public expectations have unquestionably been foremost. The survey which ran counter to public demand, as voiced by legislature or governing officials, came to an untimely death, usually from financial starvation.

Perusal of the various laws demonstrates that the primary purpose in the minds of legislators was almost without exception utilitarian, a study of the natural resources with a view to their (a) exploration, and (b) their exploitation.

Investigations for the discovery of new facts unless they have a utilitarian aspect were not contemplated. Studies primarily for the purpose of writing the history of the earth were not considered. Some of the early surveys and some of the later ones also went to pieces on the rocks of too much pure paleontology, too elaborate plans or too much topography, the value of which was not apparent. Surveys were not urged because there was any particular interest in geologic science as the key which would unlock the book on whose pages was recorded the history of our globe. Indeed, when the earlier surveys were voted, the prevalent view was that that history was adequately given in the first chapter of Genesis, a view which seems not wholly to have disappeared even at the present day. They were established because they would "create taxable values," "lead to the development of local resources," "furnish land owners reliable information regarding the value of their lands, so they would not part with them to better informed strangers at prices far below their real value."

Although their educational value, the resulting gain in the sum of human knowledge, the answer these studies might make to man's "how" and "why," were not altogether lost sight of, they were rarely if ever emphasized.

This being the foundation, therefore, upon which nearly every survey started, it has been inevitable that the economic or utilitarian phases have always been and in most states still continue to be stressed.

This does not mean, however, that the state surveys have not added largely to our knowledge of the broader problems of geology. No geologist can ever be unmindful of the debt the science owes to James Hall and the New York Survey, whose purely paleontologic studies established the New York series as the standard Paleozoic section. While New York has perhaps been the leader in this field, other states have made notable contributions. Much of this has been the result of a wise and broad comprehension of the real basis on which economic reports must rest. It is as important to determine the location of mineral deposits geologically as it is geographically. This involves more or less detailed studies in stratigraphy, the proper classification of geologic formations, possibly studies in microscopic petrography and in paleontology. Correct theories of the origin of mineral deposits are often essential to their economic exploitation; so too is an intimate knowledge of the geologic structure, the successive stages in its development, the proper sequence of deposition, folding and faulting. Again, the value of many mineral deposits depends in a large measure upon secondary changes—leaching, concentration, replacement, etc., factors unknown in large measure to the earlier geologists, but later developed by many workers, some of them upon state surveys. Solving of these problems often leads to fields at first sight far removed from utilitarian problems, but they can not be wholly neglected.

From all this it follows that while the state survey must always be primarily along utilitarian lines, this does not mean that its studies may not embrace a wide field and that the by-products of its labors may not contribute largely to the advancement of science. Moreover, it must always be borne in mind that there is a small but slowly increasing number of our clientele who are interested in the geologic history of the earth not as a means of exploiting its resources, but as history. More and more our public school teachers are called upon to present to their scholars the fundamental principles of physical geography.

It can fairly be a part of the duty of the state survey to point out how these principles can be illustrated locally; to make clear the extent to which the life of its people is guided and controlled by the geologic structure of the state. Indeed, the more clearly this can be done in all reports, the more assured the survey will be of support. Too often in the past the work of the geologist in whatever field has seemed to have no connection whatever with the ordinary everyday life of the people. The successful head of a state survey is he who can best bring this home to his citizens, without departing from the high standard of scientific investigation.

PERSONALITY

The second of the factors which have controlled and directed the work of state surveys has been the personality of the geologist in charge. By this I mean those qualities of head and heart which have made him not only an able investigator, a discriminating observer and a sound reasoner, but those other qualities, which have enabled him to inspire confidence, to judge rightly the demands of his clients, to persuade doubting Thomases in the legislature or when necessary to beat down all opposition by the very force of his unquenchable spirit and devotion to his work; in short, those qualities which have enabled him to guide his ship through stormy seas, avoiding the barren rocks of recorded but uncorrelated observations on the one hand and the treacherous sands of too much pure science on the other.

It is interesting to note in this connection that investigations which in one decade brought ruin to a survey have in later years been carried through with approval when the organization was more firmly established in public confidence, or when there was a wider appreciation of the value of that specific work. A single instance may be given. The Kitchell Survey was established in New Jersey in 1854; it died of financial starvation in 1856, after spending $35,000, a very considerable part of it for triangulation and a topographic survey—a project which, however admirable in itself, was somewhat ahead of its time. When the work was resumed in 1864 under Dr. George H. Cook, it was not until about 1880 that a topographic map was attempted and then only because further progress in geologic work had been halted for lack of an adequate base map. By that time, however, the public had been educated to the importance of an accurate map, and the completion of the topographic survey and its publication under state auspices did more to establish the geological department on a permanent basis than any other piece of work it has ever undertaken.

Every one who is at all acquainted with the work of Hall in New York, Cook in New Jersey, W. B. Clark in Maryland, White in West Virginia, Smith in Alabama, Orton in Ohio, Chamberlin in Wisconsin, to mention only a few of the state geologists who guided their organizations to firm foundations as established bureaus, or brought their more limited surveys to a well-rounded completion in accord with legislative mandate, will recognize how important has been the personality of the state geologist, in determining the scope and character of the work.

Requirements as to Publication

An annual report has been a very common requirement, a practice that has some good and some bad elements. It has required the geologist to render a frequent accounting to his clients. It has given him an opportunity to get before them some of the results of his work. The far-seeing have used it as an opportunity to win support for the work; others have overlooked its possibilities in this respect. In many states it grew in size, and in complexity of its contents, until it frequently lost its value in this respect, particularly when its publication became too greatly delayed. Too often it became the vehicle of hastily prepared "reports of progress" with conclusions which not infrequently had to be revised. Successive papers of this character may be interesting as a study in the development of an author's views, but they are a sad stumbling block to the student trying to reach the roots of a problem.

Fortunately in most surveys where this requirement still exists the annual report has now become a mere administrative report, which in most instances would never be missed if never written, and the scientific studies are published as bulletins or more elaborate reports. It is no exaggeration to say that the style, subject-matter, and time of publication of reports have been most important factors in the life or death of state surveys.

Politics

As we read the history of some state surveys, the conclusion can not be escaped that sometimes in some states they have felt the withering hand of partisan politics. Indiana for years elected its state geologist along with its governor and other political officials. Naturally the reports of that state did not deserve and did not command high standing, although this does not mean that some of the men who held the position were not good geologists. When the state in successive elections was carried by the same party, there was a certain degree of continuity in office and unity of investigation, but it was almost inevitable that the incumbent performed his tasks with one eye on the rocks and the other on his political fences. On the whole, however, so far as I know, the political spoilsman in most states has kept his hands off the surveys, perhaps as much from the fact that they had comparatively little money to disburse as for any other reason.

Recent Developments

Of recent years three movements which are more or less widespread have

affected the administration of all state scientific bureaus. These are civil service regulations, the budget system and consolidation of departments.

Civil Service Regulations

In many states civil service rules control the appointment of both clerical and technical employees. They vary in different states and, therefore, no statement can be made which will be equally applicable to all localities. I venture to say, however, that wherever the appointing officer is not subject to political pressure, and desires only ability and efficiency in his staff every civil service rule which restricts him in his freedom of appointment and regulation of salary is an impediment and not a help in administration.

In New Jersey it is invariably the case that the department must find its own technical men, and in this the Civil Service Commission is no help; it has no eligible list for this type of employee, but after the right man is found and given a temporary appointment, he is subject to a competitive examination, and it is often months after he begins work before a permanent appointment can be made. At the best there is at least the necessity of conferences with a department with no particular knowledge of the type of employee needed; at the worst there is delay, lost motion and one more administrative detail for the scientific head to bother about.

Budget

The growing adoption of the budget system in many states has complicated the accounting system, increased the administrative cost and introduced a decided element of inflexibility in appropriations. This is worse in some states than in others. Where it goes so far as to fix a year or two years in advance all expenditures in great detail, it becomes increasingly difficult to carry on the work wisely and economically. There may be a surplus for salaries, and a shortage for field expenses; too much for typewriter ribbons, which are office supplies; not enough for machines on which to use them—the latter being office equipment. If there be no machinery for shifting sums during the year, the work is often hampered because of inability to move it in certain directions. The funds of the Department of Conservation and Development of New Jersey, of which the Geological Survey is a part, are appropriated under thirty different heads, some of which are for the specified purpose only, and can not be shifted. In other instances transfers can be made with the consent of the fiscal officers of the state. Fortunately entrances to some of these stalls look much alike, and in times of emergency some items have been known to get into a stall with a full manger when their own was empty. Practically the entire time of two clerks is needed in the accounting division to keep track of the expenditure of $200,000 annually—with less red tape one would suffice.

Consolidations

In some states in recent years various bureaus more or less closely related in function have been consolidated into large departments. Illinois, Indiana, Pennsylvania, New Jersey and New York may be cited as examples. Geological surveys have been involved in many of these. In Pennsylvania the survey is, or was, until recently, a part of the Department of Forests and Waters; in Indiana and New Jersey, a part of the Department of Conservation and Development; in New York a part of the State Museum, which in turn is a part of the University of the State of New York; in Illinois it is in the Department of Registration and Education.

The degree to which the geological survey has preserved its separate identity in the consolidations varies in nearly every case. In Illinois it receives its own appropriations. In New Jersey it is one of the divisions of the department under the general board of control to which the appropriations are made, and while at present the state geologist is also director of the entire department, he may at four-year intervals be replaced as director by the chief of one of the other divisions.

Whether these consolidations have been to the advantage or detriment of geologic work depends, I imagine, in part upon the specific form of organization and in part on the personnel.

If they have resulted in placing the survey under the control of a chief, technical or otherwise, who is not in sympathy with this work, the effect may be unfortunate, particularly if appropriations are made to the department as a whole. In New Jersey the chief detriment has been the loading up of the geologist with so much work, administrative and otherwise, that he has not of recent years been able to give the time and attention to geologic work which he would like.

This, however, is not a condition peculiar to New Jersey or to geological surveys. With the increase in appropriations and the growth of all scientific bureaus, more and more have administrative duties encroached on the time and strength of the technical and scientific heads. Much as this is to be regretted, it is perhaps preferable to having them administered by those who are untrained in scientific methods of work and who may be too strongly impressed with the stop-watch methods of the efficiency engineer.

SUMMARY

From this hasty review and somewhat sketchy treatment the following conclusions seem clear:

State surveys are established and maintained primarily because of the belief that their investigations will promote the development and wise use of the state's resources, particularly the mineral resources, using the term in its widest sense.

The wise administrator will never lose sight of this fact, but will nevertheless recognize that this end will be best attained when not too narrowly limited. Many a study undertaken with no economic end in view has yielded rich returns in unexpected directions. The general educational aspect of the survey's studies can not afford to be neglected, for by them much support may be gained. In one way or another the value of the survey's work must be sold to the public through the press, by public addresses and by preliminary bulletins on topics of immediate interest.

In the earlier days of a survey when there is much to do and many resources to investigate, the work must of necessity be much more largely "practical" than "theoretical," applying these words in their commonly accepted, although somewhat erroneous usage. Later, greater refinements can be undertaken and broader problems can be considered. In no two states are conditions identical, and in some degree every survey must be a law unto itself. But in every case the goal should be an accurate and scientific study of and report on the natural resources, their conservation and development and a true interpretation of the geologic history of the state.

COMMON FOOD FALLACIES

By T. SWANN HARDING

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IN Plato's "Republic" Socrates is made to speak as follows—"There are charming people who are always doctoring and increasing and complicating their disorders, fancying they will be cured by some nostrum somebody advises them to try. . . . They have a charming way of going on and the charming thing is that they deem him their worst enemy who tells them the truth, which is simply that, unless they give up eating and drinking and lusting and sleeping, neither drug nor cautery nor spell nor amulet nor anything will be of any avail." Undoubtedly something similar may be found in the sacred books of the East which will, on close examination, usually be found to have antedated all the scientific lore of the Greeks by thousands of years; but it is the custom to imagine that science began with Greece and we shall here be conventional.

Who then but the physician should advise the patient in such cases? How competent is the average physician to advise wisely on nutrition at a time when every newspaper and magazine has space to give to the most utterly misbegotten diet fads and fancies the disordered brain of a maniac could invent?

Let us listen momentarily to Eric Pritchard, medical director of the Infants' Hospital, London. He wrote on "Common Mistakes in the Artificial Feeding of Infants" in the *British Medical Journal*, September 25, 1926. He remarked, for instance, that most physicians still adhere to the exploded view that fuel is to the engine precisely what food is to the body and that caloric value alone needs to be considered. In the light of the newer knowledge of nutrition this is gross error. He again notes that many infants are still fed whole or unmodified dry cow's milk in spite of the fact that this causes them to form the habit of over-secreting hydrochloric acid in their stomachs, and that they either die in the attempt to produce enough acid to digest casein or else suffer at a later date from stomach acidity due to their successful adaptability in earlier life.

Scurvy is a disease now well understood. Regarding this, Pritchard says: "We know, for instance, that the symptoms of scurvy in infants do not manifest themselves for some three or four months after the commencement of a vitamin-free diet. This is the reason for the astonishing practice, which is so prevalent in this country, of delaying the administration of anti-scorbutics until after the third month of life. The argument is so plausible; infants under three months of age do not have scurvy; therefore they do not require antiscorbutics. If there is one period more than another when infants, and especially premature infants, stand in need of this and other accessory factors in their diet, it is during the first three months of life." The gross and wide-spread error of the physician here is patent to any intelligent reader.

Consider a patient who has fallen ill and who goes to an orthodox practitioner. We shall assume that the doctor diagnoses hypertension or high blood-pressure. How will the physician then proceed? Nine times out of ten he will advise the patient on diet and in doing so will demonstrate that the famous British physician, Horder, was not very far wrong when he declared that the average practitioner's knowledge of nutrition in disease, regardless of the nature of the disease, is usually summed up in two words—"Drink milk!"

The physician may advise any of the following things. He may say drink certified raw milk. But just why? As a matter of fact pasteurized milk is not only demonstrably safer but it actually may often be a better food because it is likely to contain more vitamins than raw milk! This seems paradoxical, but cows producing raw milk are not usually permitted to go to pasture, and it has been demonstrated that green pasturage and exposure to sunlight greatly increase the vitamin content of a cow's milk, while a cow which is fed dried rations and kept exclusively in its stall, gives milk of very low vitamin content.

The physician will very likely say eat a great deal of coarse food—whole wheat, bran, fruit pulp, agar—anything to keep the bowels functioning freely. That is a good part truth. Bulk does have its usefulness in imparting proper consistency to the contents of the large intestine, but the coarse food theory is constantly overemphasized. For one thing coarse food particles close rather than open the pyloric sphincter (exit to the bowel) when they bound against it from the inside of the stomach; they thus do actually delay the passage of the chyle from the stomach to the small intestine, thus slowing down the digestive process. (Stiles—*Nutritional Physiology,* Edition 3. See also Alvarez—*J. Amer. Med. Soc.,* August 6, 1927.)

As a matter of fact physicians usually get much exercised over constipation in their high blood-pressure patients. Some actually advise them to take a tea-spoon of salts after every meal! Yet it has been shown that men are more disposed to high blood-pressure than women, while women are uniformly more constipated. It has even been shown that constipation has no effect on blood-pressure in men and that it actually tends slightly to lower the blood-pressure in women! (Alvarez, *Archives of Internal Medicine,* 38, 158, and *Physiological Reviews,* July, 1924, 352; MacWilliam, *Physiological Reviews,* July, 1925.)

Physicians will usually say avoid salt in hypertension. Yet salt is very necessary to the human economy. For digestion to function properly there must be chlorides in the blood and a large portion of our body chlorides reaches us as common salt. Even people with high blood-pressure should have good digestion. Furthermore, experiments have shown that the amount of salt eaten, even when varied within relatively large limits, does not affect the blood-pressure one way or the other. (MacWilliam, *Physiological Reviews,* July, 1925.)

Another common warning to such patients is "Cut down on meat." But just what has the physician in mind? In so many cases he, being also human, bespeaks a common convention without thought of scientific background. Sometimes when he rules out meat he has his mind vaguely on the patient's kidneys. But high blood-pressure has never been demonstrated to be a factor in the etiology of Bright's disease. Focal infection is as likely a cause as any, although even that is debatable and the etiology of nephritis remains a baffling problem. (See "Why Infection?" Nicholas Kopeloff.)

Furthermore, most abnormally high protein diets continued throughout the major fraction of the lives of experimental animals have not been definitely shown to cause kidney lesions, or anything else save a slight hypertrophy, an hypertrophy composed of normal, healthy, functioning kidney tissue, having no pathological significance, and soon disappearing after the reinstatement of a normal diet. Human experience also shows that normal amounts of meat can not be held to cause kidney trouble. They do not even cause hypertrophy. It is very doubtful whether they cause any deleterious effects. (Osborne, Mendel, Park, Winternitz, *Journal of Biological Chemistry,* 1927, LXXI, 317–50; Jackson, J. B. C., 1926, LXVII, 101; Osborne and Mendel, *Proceedings* National Academy of Science, 1921, VII, 157; McCollum, Simmonds, Parsons, J. B. C., 1921, XLVII, 126; Reader and Drummond, *American Journal of Physiology,* 1925, LIX, 472; Sherman, "Chemistry of Foods and Nutrition.") Finally it has been shown that the blood-presure is entirely unaffected by very considerable differences in the protein intake. (Alvarez, *Physiological Reviews,* July, 1924.) See also J. J. MacWilliams, *Physiological Reviews,* July, 1925, 303–335.

The physician advises a little tonic and he may even prescribe iron and syrup of hypophosphites! Why? The normal diet contains ample iron, an element the body always uses economically anyway. (Sherman, *op. cit.*) Syrup of hypophosphites has been proved to be inert physiologically; it is not a food; it has no therapeutic value and its use is simply an affront to sound therapy. (Marriott, *Journal of the American Medical Association,* 1916, LXVI, 486.)

The physician may next say, "Your urine shows a very high uric acid. That comes from eating too much meat. You must curtail your use of red meats." One patient remarked abstinence from meat for a period of two years prior to this examination. The physician hoisted an eyebrow, smiled quizzically, remarked that the analysis must be in error—which it was of course—and then gave the patient the only bit of rational advice in his arsenal. He said, avoid emotional excitement. And emotional excitement affects blood-pressure more rapidly and more powerfully than any known factor. (MacWilliam, Alvarez, *Physiological Reviews.*) The lecture on nutrition is ended; the patient is dismissed.

This indictment seems severe and perhaps based upon insufficient data. But it must be reflected that dozens of physicians voice these ideas and that such fallacies are held as fact by an important group of orthodox medical men. Physicians are not to be denounced as wilfully ignorant; that would be mere venom. What is needed and what most physicians want is medicine practiced scientifically and in harmony with the latest advances in physiology and in biological chemistry. This will require an effort on the part of laboratory investigators to acquaint the physician quickly with their assured findings as well as an alert curiosity on the part of the physician to inform himself of advances in laboratory work and to appreciate their fundamental importance.

When The American College of Surgeons met in Washington, D. C., in early 1927 there was a public health meeting in the auditorium of the District Medical Association. There were accommodations for half the people who came. The surgeons erroneously assumed that the entertainment provided by an East Indian Swami, who was then performing locally, would cut the attendance to the vanishing point. At the public meeting a half dozen of America's most noted surgeons addressed themselves to different aspects of one subject, "Longevity." Not a single speaker emphasized the importance of proper nutrition! They said, have an annual medical examination; go to an expensive hospital and bankrupt yourself on the slightest provocation; exercise more than is good for you; have offending organs ruthlessly excised; choose sturdy ancestors—but they one and all ignored the most important factor in preventive medicine and longevity, how to eat.

When Andrew Balfour, C.B., C.M.G., M.D. Edin., director of the London School of Hygiene and Tropical Medicine, addressed The Scientific Medical Conference at the University of Rochester, New York, on October 26, 1926, he took as his subject, "Through the Maze of Medicine." He then outlined various aspects of a more ideal medical education. He mentioned nutrition just once, and that was to say that medical students should be taught the rôle of vitamins in warding off deficiency diseases.

In other words, physicians too frequently ignore nutrition. They too frequently discount laboratory investigations as poppycock. Yet hundreds of diet fanatics pander to the public desire for knowledge by propagating all sorts of unscientific fake diets. We have just heard the dicta of a complex of numerous orthodox physicians in the presence of a specific symptom complex, or syndrome. Indeed some individual physicians will advise nearly every item in the composite list. Such physicians really have little more to recommend them than quacks. For instance, there actually is in Washington a reputable stomach specialist who holds that prunes should not be eaten because they "rot the intestines!" He has probably learned that prunes, like a few other fruits, generate benzoic acid in the organism. But the body is amply provided with apparatus to throw off excess benzoic acid; it can not rot the bowels. But let us analyze a few more ridiculous food fallacies garnered from various physicians and non-medical *soi-disant* nutrition experts.

Our presumption is not that the nutritional investigator knows everything; indeed the fragmentary character of his knowledge should be contrasted with the dogmatic self-assurance of the quack. But he has established certain fundamentals and these the physician often ignores as negligently as the quack.

A clinical analysis showed that a certain patient had gastric hyper-acidity—too much stomach acid. A practicing physician advised that patient never to eat an acid fruit—lemon, lime, orange, grape-fruit. This means that there are actually some physicians unaware of the well-established fact that these acid fruits in the end contribute alkali to the organism. Furthermore, such organic fruit acids are so slightly ionized, that is they are such weak acids, that their contribution to the stomach acid—which may normally run as high as one half of one per cent. of the strong, mineral acid, hydrochloric—can not be other than negligible.

This patient was advised by two physicians to take sodium bicarbonate regularly. Certain authorities (Stiles, *op. cit.*) hold that while sodium bicarbonate does initially reduce stomach acidity, there is an almost immediate rise thereafter which over-compensates and makes the stomach more acid than it was at first. (Crohn, *Journal of the American Medical Association,* 1918, 155, 801.) Other authorities deny this but hold that the stomach may, in pathological conditions, empty with abnormal rapidity and that as soon as it does so a rapid acid secretion takes the place of the ejected bicarbonate. (*Bulletin,* Johns Hopkins Hospital, 1927, Keefer and Bloomfield.) In short, the problem is far from settled and the use of bicarbonate here is purely empiric.

The body is always making automatic and usually successful efforts to adjust itself to the variations in the food we give it towards the end of retaining its internal integrity as much unaltered as possible. For instance, the blood, gastric juice and intestinal juices of the same individual have the same salt content as is evidenced by the fact that they have the same freezing point.

This condition must be maintained. Now it has long been known that certain types of plain dyspepsia yield as readily to doses of hydrochloric acid as they do to doses of bicarbonate of soda. It is curious at first to find that the administration of an acid seems as potent to aid an "acid" stomach as the administration of an alkali. The reason is the constant salt content of the juices mentioned. Now if chyle from the stomach containing less salts in solution than the normal intestinal juices of the patient does enter the small intestine, the intestine promptly rejects it back into the stomach to protect its own delicate walls. The patient regards this regurgitation as evidence of an acid stomach. Yet it is a regurgitation from the intestine, and the stomach may be twice or thrice as acid as normal without the patient being aware of it.

In this type of dyspepsia where the stomach salt contents are too low—it may have been the high blood-pressure patient who has stopped eating salt on the advice of his physician—either hydrochloric acid or sodium bicarbonate can be administered with good results. For either one will raise the freezing point of the stomach contents, and the small intestine will then no longer reject the spurts of chyle from the pylorus. Digestion will proceed minus the belching and the sense of fullness, for the stomach is emptying normally. (Apperly, *Medical Journal of Australia,* 1926, XXVII, 354; *Journal of the American Medical Association,* 86, 1847; *British Journal of Experimental Pathology,* June, 1926; Van der Laan, *Biochemische Zeitschrift,* 1915, LXXI, 289; LXXIII, 313, 1916.)

Let us return to food fallacies. A popular admonition is "Avoid an acid diet!" A tendency towards dietary alkalinity is preached as eloquently as if there existed incontrovertible experimental evidence to show that a long-continued acid diet is injurious. There is no such evidence. In fact, while a tremendously acid-forming diet had no ill effects on experimental animals at all, a long-continued alkaline diet did have definite bad effects. (Addis, MacKay, MacKay, *Journal of Biological Chemistry,* 1926, LXXI, 157.) (Sherman, *op. cit.,* page 296.)

Nor has an acid diet yet been shown to cause nephritis. Again the body's tremendous reserve power of adjustment must be remembered. It is plain that the body can easily adjust to or neutralize the acid or alkali excess of any normal diet. This is not to advocate a purely acid-forming diet of meat and egg yolk. The idea is simply to draw attention to the fact that fanatics constantly overemphasize a factor here which can not yet be proved to have the importance they attach to it.

As a matter of simple fact lowered blood alkalinity and what is clinically called "acidosis" are concomitant, but this does not necessarily relate them as cause and effect. The proteins, the phosphates and the hemoglobin of the blood enable it to carry large excesses of acid without any alteration whatever in its normal reaction. The true alkaline reserve of the body is not the blood bicarbonate of soda, formed in part by eating fruits, but the blood hemoglobin. The intensity of blood alkalinity is a function of the respiration rather than of the diet.

The causes for the variations in the blood reactions are not acid-alkali neutralizations such as occur in test-tubes; they are deep-seated respiratory and metabolic changes which are imbedded in the intricacies of cellular life and are not yet thoroughly understood. The prevalent emphasis upon acid diets and "alkaline reserves" is unscientific. In fact, as L. J. Henderson says, "within wide limits of amount any acid or base may be poured into the organism, and the reaction will not vary . . . the urine is variable, the ingesta are variable, even the products of metabolism are variable; but while life endures," the body reaction persists essentially unaltered. (Henderson, Y., *Physiological Reviews*, 1925, V, 131; Wilson, same, 1923, III, 295; Henderson, L. J., *Science*, 1913, XXXVII, 389, and Harvey Lectures, 1914–15, "Excretion of Acid in Health and Disease.")

To return to the dogmatic faddists, we shall use quotation marks to set off their pronouncements. "Milk, starch and fruit is an acid-forming combination." This would depend altogether upon how much of each element you had in the combination, for certain fruits could readily render it alkaline. "Never eat but one kind of starch at any meal." This prohibits a necessity that one can scarcely avoid and eat at all; eating ordinary foods you are almost bound to eat starches from more than one source at the same meal, although there is obviously no reason for two major starch dishes at one meal.

One of the most insane food fallacies is that which appears over and over again in the admonitions of quacks and is even subscribed to by some regular physicians —"Do not eat proteins with starches!" Nothing could be more absurd, for no harm whatever inheres in this procedure so long as whole wheat bread or beans digest well. Nature continually supplies this very combination in legumes and cereals and we are not accustomed to pry protein from starch before eating. Milk itself contains a complex carbohydrate and protein. Furthermore, when proteins are eaten they unite with the stomach acid and thus tend so to lower stomach acidity that there is more likelihood of alkaline salivary digestion proceeding unimpeded than if protein were not present to absorb some acid. Pragmatically the habit of eating starches with proteins is above reproach, for healthy people do this habitually and without detriment. (See Stiles, *op. cit.*, for proteins uniting with stomach acids.)

Indeed, no conclusive evidence exists in the literature to show that a subnormal rate of any of the alimentary processes is caused by the addition of carbohydrate to a diet. On the contrary, the report of Cannon (*American Journal of Physiology*, 1904, XII, 387) that a mixture of carbohydrate and protein foods leaves the stomach more rapidly than protein alone "makes it very probable that the addition of carbohydrates to the diet accelerates digestion and the discharge of the gastric contents." (Mendel, Lewis, *Journal of Biological Chemistry*, 1916, XVI, 37.) The idea embodied in the warning against eating proteins and starches together is a food fad of the most vulgar sort, yet perhaps millions of neuropaths and near psychopaths follow the admonitions of ignorant physicians and palpable quacks in this matter.

Again, we hear, "Exile granulated sugar! Eat only simple, predigested sugars like honey or maple-sugar!" There is nothing harmful about granulated sugar; it might become harmful if some imbecile ate so much of it that other foods were neglected, but used with judgment it is harmless, even beneficial. Few ever eat it to dangerous excess. Sugar can not cause stomach fermentation, because the high acidity there probably renders fermentation in the stomach impossible anyway. (Hurst, of Guy's Hospital, London, *British Medical Journal*, October 2, 1920, 501.)

In addition the body is well provided with enzymes and acids which break down the twelve-carbon cane-sugar—sucrose is its chemical name—into the only sugar the body can directly utilize, the simple six-carbon sugar called glucose or dextrose. Milk-sugar has even to be broken down to glucose and it is just as difficult for us to digest as sucrose; yet nature supplies milk-sugar (lactose).

Nor is there any specific food virtue in honey beyond its pleasing flavor. It contains no vitamins. It is of course partially digested, because it consists of one half glucose and one half fruit sugar (levulose or fructose); both six-carbon, simple sugars. But the fructose has to be made over into glucose by some mysterious alchemy in the organism before the body can utilize it, so half the honey also has to be worked over. Indeed, glucose is usually stored first in the liver as a kind of complex starch called glycogen; it is then drawn out from this organ into the blood as needed, the glycogen simplifying into glucose for the purpose.

Maple sugar, on the other hand, is, as is generally known, except for a few physicians, simply the same old twelve-carbon sugar, sucrose, found in the beet, in the cane and in the sorghum. It is true that honey and maple sugar contain more mineral matter than cane sugar, but the minerals are not particularly valuable. Potassium, of which we always get sufficient, predominates. The calcium in maple-syrup is about the same in amount as in milk, but one would have to use a quart of maple-syrup daily to get an ample supply, and who would do that? Honey contains a negligible amount of calcium, the element we are most prone to lack in our diet. (Sherman, *op. cit.*)

"White of egg promotes acidosis and autotoxemia." This is really rather amusing to the chemist who is aware that investigators always use egg yolk when they want to give animals a highly acid diet experimentally. (Sherman, *op. cit.*, page 296.) The sulfur content of the yolk also makes it far less likely to cause intestinal putrefaction than the white. Of course the yolk contains valuable vitamins and proteins; but it is high in acid-producing qualities and the white is not.

"Chew long and well. Chew starch to a liquid state." This advice seems to ignore the fact that during a meal the stomach is packed with food from the center outwards, thus gradually forcing the walls apart to store food layer upon layer. Just so food is thoroughly moistened with saliva in the mouth, then alkaline salivary digestion can continue in the center of the massive food bolus in the stomach long after a meal. It actually takes quite a while for the stomach acids to eat their way into the center of the alkaline ball of food stored in the upper part of the stomach where the walls do not move appreciably anyway. (Stiles, *op. cit.*, on Salivary Digestion.)

"The bread, butter, meat and potato mixture is a very harmful food combination." This is almost grotesque. If such combinations of food elements are harmful then milk must be harmful, for it too is composed of protein, fat, carbohydrate and mineral matter. The mixture is, instead, the rational basis for an excellent diet; add some raw or nearly raw leafy vegetables and milk *ad lib* and you have a complete ration.

"Cooking ruins food. Cooking is civilization's curse to food." Raw food faddists widely preach this unadulterated gospel. Even many physicians emphasize raw food too strongly. Of course we need some raw food. And cooking carelessly (usually too long) will render vitamins inert. But at the same time cooking is far from being civilization's curse to rational food. Instead it actually renders certain meat and legume proteins very much more digestible and useful to our organism. (Jordan Lloyd, "Chemistry of the Proteins.")

A very curious example of diet fallacy might well be mentioned here; that is the time-hallowed theory that raw egg white is a singularly nutritious food, easily digested and rapidly assimilated. Many physicians still promote this fallacy, yet nothing could be further from the truth. Mendel and Lewis (*Journal of Biological Chemistry*, 1916, XXI, 55) and Bateman (same, 1916, XXVI, 263) separately demonstrated that raw egg white is exceedingly indigestible, although slight cooking would immediately render it biologically useful. Dietitians are, therefore, always in error when they assume that a raw egg is especially digestible; the egg slightly cooked is at its best.

Then, again, bread has been found to be much more digestible and much more useful biologically than raw cereals. Raw rice has, indeed, been found to retard the growth of experimental animals and the same holds for puffed rice! (Morgan, *Proceedings of the Society of Experimental Biology and Medicine,* 1926, XXIII, 353; Waterman, Jones, *Journal of Biological Chemistry,* 1921, XLVI, 9; XLVII, 285.)

Of course, we may expect anything of faddists and quacks, as *The Journal of the American Medical Association* always robustly assures us, and as any regular physician will at once aver. But why should an active legitimate physician, for instance, tell a man not to eat eggs because they make the blood a good culture medium, thus promoting infection? A prominent physician recently gave that advice, whereas blood is normally an ideal culture medium for bacteria and egg proteins can yield to it only some of the score or so of "amino acids" into which all proteins break down during digestion. No proteins can pass directly into the blood stream as such; if they did so the consequence would be disastrous.

A physician has recently written a guide to nutrition in which he actually says, "Eat only one protein food at any meal." This is precisely what we should never do. Proteins, as noted above, are built up of simpler substances called "amino acids." There are about twenty of these and we perhaps need most of them to build our own tissues. One protein will very often supply the amino acids which are deficient in another protein and may thus become limiting factors in our nutrition, hence protein combinations buttress each other and are just exactly what we should eat in order to be assured that we get all the varieties of amino acids we need in tissue-building. This is a well-established fact as reference to Stiles, "Nutritional Physiology," will show. (See McCollum, *Journal of Biological Chemistry,* 1916–7, XXVIII, 483; 1917, XXXII, 303; 1919, XXXVII, 155–158.)

A prominent stomach specialist recently told an ulcer patient of his not to eat sugar but to eat all the honey he wanted! This is absurd when you remember that honey is simply sugar. Why do orthodox physicians often presume to advise so freely and so mistakenly on diet? There are actually still practitioners who tell nursing mothers to avoid emotional excitement as it will poison their milk! Yet this is a metaphysical assumption without evidential background save of the type that "proves" miracle.

Three arresting considerations stand out.

1. Physicians are either improperly trained in nutritional physiology or else they make no real effort to absorb the authoritative facts regarding the subject later in life. Perhaps facilities have not been sufficiently perfected to enable them to get really reliable information that they can use practically. Certainly medical education stresses a large amount of purely theoretical physiological chemistry entirely too much, and to the utter confusion of the medical student, when much less time spent upon certain established fundamentals of practical value would better train the future physician. In later life physicians tend to catch here and there an assumption—perhaps in some chance article, perhaps from a group of essentially uncontrolled clinical cases—and that casual impression becomes with them thereafter an article of faith and a permanent dogma.

Experiments may disprove the idea, clinical records of controlled cases may refute it statistically, common sense may find it revolting, but it remains to the particular physician an unalterable, inerrant procedure for all time and for all patients. Yet human beings are seen by science to be more definitely individualized than was ever before imagined, when biological tests were less delicate than now, and no two clinical pictures of the very self-same disease are ever identical.

2. Perhaps physicians do not know where to go for reliable information on nutrition. Very often if they do stumble upon the right authority they are casual and hasty and seem to gather fragmentary or erroneous impressions from what they read. This arises largely from the old antipathy between clinical cases and physiological experiments. The physician has luck with certain dietetic procedures in a few specific but, from the standpoint of rigid physiological experimentation, essentially uncontrolled cases. Then, just like a quack, he makes a snap generalization from insufficient data and proceeds thereafter upon this theory forevermore. The scientific biological or physiological chemist works on carefully inter-bred, rigidly controlled experimental animals under meticulously regulated conditions and he gradually piles up masses of results upon these standard animals which lead to the formulation of really reliable conclusions. He then generalizes cautiously and his generalizations have real value.

The physician constantly voices the ignorant layman's stock objection—but what do experiments with rats or dogs or guinea pigs have to do with the physiological processes of human beings? A very great deal. Nearly all therapy is founded upon animal experimentation. For one thing, certain animals, like the rat, are very similar to man in diet and in nutritional physiology. These animals can be bred under standard conditions throughout many generations over long periods of years. Finally the individual rat is as near a physiological unit standard as can possibly be produced. Human beings would be vastly better of course, but they simply can not be bred intensively throughout dozens of generations to be used in nutritional experimentation. Yet results on standard rats are found time and time again to have human applications. While we should prefer human standards, rats must be used in fault of better, but these rats are far more reliable in their reactions than uncontrolled and diseased human beings under the doctor's very fragmentary supervision. Yet the physician remains skeptical.

3. There is no unalterable rule of diet universally applicable to all men. Human beings differ in health and in disease. Individual measures must always be invoked. Diets also are made up of a large number of essentially individual factors. No dogmatic rule can be laid down. Individuals must try to adjust these various diet factors to their personal needs, judging largely by their state of health. Of course certain basic principles exist with which all practicing physicians should thoroughly acquaint themselves in order to advise their patients wisely on nutrition problems. It would also be a great help if papers and periodicals which glory in printing the most highly technical food-fad systems would get over their aversion to the publication of the plain, fragmentary facts about scientific nutrition in order to instruct intelligent readers. The faddist, the fanatic, the quack or the physician can not avoid error when they extol some universally applicable diet system in health or in disease. It is melancholy to consider the false information dispensed so widely on nutrition.

In conclusion the nature of the basic principles will be very briefly indicated. McCollum has long emphasized the fact that the American diet is to-day deficient. Such a diet, consisting of milled cereals, legume seeds, meat and deficient amounts of milk have proved inadequate in calcium and in vitamin A and have prevented rats from reaching maximum size or exhibiting maximum fertility.[7] A menu made up of such food does not appear so frightful. For instance—

Broiled Steak Mashed Potatoes
Buttered Beets Combination Salad
(Or Gelatin, Peas or Carrots)
Bread Butter Sweet pickles
Apple Pie Cheese Coffee

"When a family is confined to such food supply throughout several generations, the physical development gradually deteriorates. They show signs of senility rather early and fail to maintain a well-nourished appearance," writes McCollum. It is only necessary to add calcium and fat soluble A vitamin to change this picture completely. In other words, milk consumption must rise from half a pint to a quart *per capita,* since milk is the most accessible source of calcium we have. The consumption of butter, cheese, creamed soups, leafy vegetables, greens and salads must increase. Most important are such vegetables as spinach, turnip, beet tops, celery leaves, romaine, collards, lettuce, cabbage, cauliflower, endives. Legumes, cereals, tubers and fleshy roots, it must be remembered, are calcium-deficient and calcium is an absolute essential.

We may therefore conclude that if a person will drink ample milk and eat freely raw or lightly cooked green vegetables and raw fruits—to round out the ordinary basic diet, the fundamental requirements of nutrition have been fulfilled. Other adjustments are largely a matter of taste.

We do not for a moment conclude that the nutritional laboratory investigator knows it all. We are trying to show that what is actually known as fact to the scientific investigator in nutrition is as nothing compared to the vast assumed knowledge of *soi-disant* diet "experts" and food system faddists. We must learn that scientific nutrition rightly lags far behind these grandiose evangels with their assured "truths." But slowly and laboriously the foundation is being placed for a science of nutrition that will be immeasurably valuable because it is rigidly scientific. All people of intelligence should know about this. They should be eager to know of scientific progress rather than eager to follow the syndicated words of sciolists.

THE ACTION OF ALCOHOL ON THE BODY AND ON ITS OUTPUT OF WORK*

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INTRODUCTION

IN a discussion of the effects of alcohol on the body, we are confronted by two outstanding questions: What does alcohol do to the body and how does it do it? In considering these questions we shall look first at its action on single exposed cells. Second, we shall study its action on an organ separated from the body, and, third, we shall consider its effects on the whole body.

We may say summarily that: (1) It takes a concentration of alcohol as high as two per cent. to cause permanent injury to a single free swimming cell; (2) a concentration of one eighth per cent. does not injure an organ like the heart when that organ is removed from the body and kept active, but (3) the same concentration, one eighth per cent. in the blood stream, may seriously injure the whole body. Indeed, one half of one per cent. in the blood stream not infrequently causes death. We shall see further that the advantage which alcohol in the blood stream has over alcohol bathing a muscle is that in the blood stream it has ready access to the brain. The brain is the organ in command of the body, but at the same time it is the one organ of the body which is most susceptible to the action of alcohol.

Let us look in detail at the three types of experiments.

ACTION ON EXPOSED CELLS

If we add a sufficient amount of pure alcohol to a medium in which unicellular organisms live so as to bring the medium to a one per cent. alcoholic solution, the first effect to be noted is on the behavior or activity of the cells. In most cases after a moment of quiet, the organisms become active and move rapidly about as if attempting to escape injury. If the alcoholic concentration be increased to two per cent. the cells may or may not continue motor reactions. They contract and round up. In a concentration of four or five per cent. the cells swell up and rupture and the protoplasmic contents run out, thus causing the death of the cell.[1]

ACTION ON GROUPS OF CELLS OR AN ORGAN

We may test the action of alcohol in known percentages on a given organ, for example, a muscle, by isolating the organ from the body. By this means we may ascertain at what strength the alcohol first has a *direct* effect on the muscle and we may then study the nature of the effect. Let us look briefly at the problem involved if the isolated heart is the muscle considered.

Martin and Stevens early found that alcohol could be added to defibrinated blood and then this mass passed through the isolated heart of the dog. When the alcoholic concentration was kept at one eighth per cent., the mass had no apparent effect on the heart muscle. At one fourth per cent., however, it usually lowered the activity of the heart and at one half per cent. it resulted in a rapid and marked diminution of the work done by the heart. From these experiments, it appears that alcohol of one eighth per cent. has no effect when applied *directly* to the heart muscle. In fact, it is not until the concentration reaches or nears one fourth per cent. that an effect is discernible.

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* The fourth of a series of articles on "Alcohol from a Scientific Point of View."

[1] Daniel, J. F., *Journ. Expt. Zoology*, Vol. 4, p. 575.

When the heart is intact in the body and integrated with the nervous system it is difficult to make certain just what action the alcohol has on the heart as an organ. We know that alcohol simply held in the mouth may quicken the heart beat, but this effect is neither prolonged nor profound. A similar result may be obtained from a number of other irritants. As to effects other than these which are temporary, we are little informed. Dodge[2] in summarizing the results of the many studies made on the effect of alcohol on the pulse rate shows that the experiments on this subject divide themselves into four groups. In one group, alcohol definitely increases the pulse rate; in a second, it decreases it; in a third, it neither increases nor decreases it; and in a fourth, it both increases and decreases it. In contemplating these results, our first impulse is to reject them as inaccurate and valueless. But many of the experiments, under the conditions studied, were very accurate. From these studies one thing is clear, and that is that the heart with its complex system of accelerators and brakes is a superbly stabilized mechanism which alcohol can overcome only provided it be administered in relatively large doses.

In order to insure a concentration of one eighth of one per cent. alcohol in the circulation of a man of 150 pounds weight, Abel[3] has shown that it would be necessary to give the equivalent of about six ounces of whiskey in the course of a single hour, a dose which in most cases would produce intoxication. We have seen, however, in the experiments of Martin and Stevens that this concentration has no effect on the heart when isolated from the body. Why is it that the same concentration may have so marked an effect on the body when the heart is intact?

It has long been known that alcohol readily injures the nervous system which is in control of the orderly functioning of the body; but even to-day it is not certain just how this effect is produced. An example will illustrate this point. Normally, there is a beautiful adjustment between the nervous system and the muscular walls of the blood vessels of the skin, regulating the amount of blood which goes to the surface. Alcohol, often in small amounts, destroys this adjustment and as a result, too much blood rushes to the skin. Does the alcohol in this case act on the nerve centers; or on the nerve fibers, running from the center to the skin; or does it act on the connection which the fibers make with the muscles in the walls of the blood vessel? The best evidence which we have at present indicates that the action is on the nerve center in control of the muscular wall. By action on (depressing) this center, alcohol is able to cut off the nerve impulse to the vessel and consequently to leave the muscle practically in a state of paralysis. The muscular walls of the vessels thus released from the integrating action on the nervous system relax and the caliber of the vessels increases enormously in size. As a result of these several steps the blood under pressure from the deeper vessels rushes to the surface, and the face and upper parts of the body flush pink.

If the injuries of alcohol are primarily through the nervous system, it would appear that one of the factors in the degree of injury would be the degree of development of the nervous system. In a man with numerous highly developed nerve centers alcohol would undoubtedly have a wide field of attack, for in him alone are found certain of the more complex centers, like that of speech for example. But its effects on certain types of coordination, for example, on locomotion, might be expected to show themselves earlier in man because of his method of locomotion. I shall consider the latter point first.

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[2] Dodge, R., and Benedict, F. G., Carnegie Inst. Publ., Washington, No. 232, pp. 186–7.

[3] Abel, J. J., "Physiological Aspects of the Liquor Problem," Vol. 2, p. 50.

ACTION ON MUSCULAR COORDINATION

One of the most prominent symptoms of the action of alcohol is the general incoordination which it produces in the muscles of the body. Especially is this true in those muscles associated with locomotion. According to Mellanby,[4] the steps in the development of this condition in the dog, while not exact, may be followed in a way. The first symptom of incoordination in the locomotion of this animal is the dragging of its hind toes. This generally occurs at a time when the concentration of alcohol in the blood reaches about 354 cubic millimeters per 100 grams of blood. Following this step are others, such as weakness in the hind legs, stumbling, difficulty of getting up after falling, inability to walk and finally complete collapse. The degree of injury to the coordination of the muscles is here reflected in a series of steps which become more and more pronounced until finally muscular coordination is entirely destroyed.

In man alcohol acts on the muscular coordination involved in locomotion earlier than it does in the dog. The main reason for this is easily understood. It has been pointed out that the dog first shows weakness in its hind legs and that this weakness makes it more difficult for the dog when intoxicated to stand still than to walk, for by walking the faltering of the hind legs is, as Mellanby (*loc. cit.*, p. 31) says, compensated for by the front legs and the muscles of the body. In a bipedal type like man, however, the whole support of the body depends on the legs, but here the base is relatively small. As a consequence, balance is difficult and any unsteadiness is early detectable. The breaking down of the coordination of the muscles of locomotion, then, is more readily attained in man than in the dog. This would be true regardless of whether alcohol acts in a more pronounced way on the nervous system of man than on that of the dog; it would affect his locomotion earlier because it acted on a more delicately adjusted mechanism.

To illustrate in a simple way the extended field of attack we may cite an example, also in muscular coordination, in which the movements of the hand, the arm and the eye are involved. The following series of drawings (Figure 1), made by a man after taking whiskey indicates the character of the effect in acts of this sort.[5] Here it is seen that the alcohol is more and more effective in breaking down coordination up to a certain maximum for the dose. While the first drawing shows irregularity, it is not until the third, made fifty-five minutes later that incoordination is at its maximum. It is at about this time, as we have shown in a former article,[6] that the alcohol reaches its highest concentration in the blood and presumably has its greatest effect on the nerve centers.

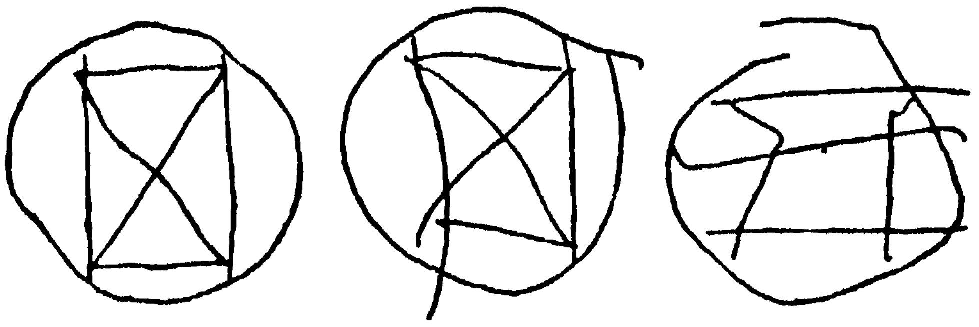

FIG. 1. DRAWINGS MADE BY A SUBJECT AT DIFFERENT INTERVALS (27, 43, AND 55 MINUTES) AFTER IMBIBING WHISKEY. FROM MELLANBY.

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[4] Mellanby, E., Report No. 31, 1919, Med. Research Committee, London.

[5] Mellanby, E., *British Journ. Inebriety*, Vol. 17, p. 175.

[6] Daniel, J. F., THE SCIENTIFIC MONTHLY, Vol. 18, p. 160.

Beyond this time, coordination rapidly improved.

ACTION ON OTHER TYPES OF COORDINATION

The action of alcohol on pure muscular coordination, however, is only one of a number of ways in which alcohol may express itself in man. Some of the ways, as is well known, involve complex psychical factors as well as physical factors. It is a common observation that man under the influence of alcohol may become garrulous and that this symptom of the activity of the alcohol may appear early, like the purely physical coloring of the skin.

If this reaction be compared with that on muscular coordination, the two may at first appear to be diametrically opposite in effect. In the case of muscular coordination, as we have seen, alcohol by removing certain inhibitions, impairs the normal functioning of the body. It renders locomotion difficult, the execution of a drawing inexact, and the contraction of the cutaneous blood vessels well nigh impossible. In case of the effects now under consideration, alcohol appears to assist function. The subject talks more freely and his ideas come without effort. Inwardly he marvels at the fluency of his expression. He would say that never before was his conversation so effective or his opinions so much appreciated. If, however, his expressions be dictographed and reviewed by him after the effect has worn off, they would make a different impression on his mind. Although his conversation was voluminous, it was inconsistent and emotional.

In the above reaction, then, alcohol has also impaired function. By releasing inhibitions a more voluble expression results, but the character of the expression indicates impairment of judgment.

By the possession of these various indicators which we have cited, man should become an unusually good type on which to study the action of alcohol were not the difficulties of the problem so great. But let us examine more minutely the effect of alcohol on the output of work beginning with the simplest muscular acts.

EFFECTS OF ALCOHOL ON WORK

Many of the earlier experiments dealing with the effects of alcohol on muscular activity dealt with complexes so involved that an analysis of any part of the complex was, at the time, difficult or impossible. For this reason it was found desirable to plan experiments which if possible dealt with simpler activities or reflexes of a kind divorced from the influence of volition. Such an experiment on a reflex act would inform us of the action of alcohol on that reflex arc in terms of how the muscle acted, whether its activities were increased or decreased. This could be measured mechanically and accurately. In recent years, important work of just this sort has been undertaken by the Carnegie Nutrition Laboratory and I shall refer briefly to the parts of the report by Dodge and Benedict (*loc. cit.*) dealing with the action of alcohol on the knee-jerk and on the protective reflex of the eyelid.

EFFECTS ON SIMPLE REFLEXES

In experiments on the knee-jerk, the tendon below the knee was struck and the contraction of the muscle of the thigh (the quadriceps) was recorded. The questions raised were: (1) Will a moderate dose of alcohol (29.8 cc) hasten or check the promptness with which the muscle contracts; and (2) Will it increase or decrease the amount of the contraction? As a result of these experiments it was shown that in five

men out of six the response or promptness of the reflex was slowed down almost ten per cent. (9.6 per cent.) and the extent or height of contraction decreased nearly forty-nine per cent. (48.9 per cent.). As regards both promptness (latency) and extent (height) of contraction, therefore, a moderate dose of alcohol produces a depression of the knee-jerk or patellar reflex.

The protective eyelid reflex has a normal latency equal to that of the knee-jerk. Because of this fact it was considered a satisfactory reflex to compare with the knee-jerk. In addition it has the advantage of representing a higher level than the patellar reflex. The stimulus used in the protective lid reflex was auditory, and was made by closing a wire-loop hammer against a sounding-board. In these experiments, record was taken by photographing the shadow of the eyelash as a "bat" of the eye. The dose of alcohol (29.8 cc) checked the latent time or the promptness with which the eye-bat occurred in four out of six subjects by an average of more than five per cent. (5.9 per cent.). It also decreased the extent of movement in five out of six subjects by an average of more than ten per cent. (10.7 per cent.). Furthermore, forty-five cubic centimeters of alcohol increased the latency in five cases out of six, 9.5 per cent. and decreased the extent of movement 28.5 per cent.

In both of the experiments given above, moderate doses of alcohol reduced the efficiency of the muscle.

EFFECTS ON SKILLED ACTS

A voluntary act like that of typing which includes a number of mental attributes, such as attention, memory and the like, may with practice become almost automatic. In a nicely adjusted activity of the sort, what will be the effect of alcohol on speed and on accuracy of performance? To test these two questions Vernon[7] has recently made an extended series of experiments which consisted in typing a memorized passage successively before and after the ingestion of alcohol. After the control experiments were repeated at twenty-minute intervals alcohol was given and the typing was continued for the subsequent two and one half to three and one half hours. The alcoholic liquids used were taken over an interval of one half hour and were taken practically on an empty stomach.

As regards speed the results are not convincing. They indicate that the typing time was increased in all but three of the examples, and an increase in typing time would, of course, indicate loss in speed. As to the effects on accuracy the results are very suggestive. Vernon found that, under alcohol, the errors increased in some cases as much as fourfold. He found, further, that when the alcohol was taken on an empty stomach, its effects were about twice as great as when taken with meals. Vernon cites one subject very susceptible to alcohol, who, after taking 11.2 cubic centimeters (less than one half ounce) of pure alcohol on an empty stomach, made an increase of 88 per cent. of errors. Another subject, after drinking sherry containing 22 cc of alcohol, made an increase of 156 per cent. On the other hand, some subjects took port containing 18.5 cc or ever 22 cc of alcohol with meals without showing any "measurable reaction."

Miles[8] has recently (1924) published a careful series of experiments on the effects of moderate quantities of alcohol on typewriting efficiency, which agree with the results of Vernon. In these experiments young men trained as typists were used as subjects. A practice period of two days was given and followed by a period of four days, two of which were control and two alcoholic. The alcoholic dosage "A" was about 0.5 cc. of absolute alcohol per kilogram of body weight; dosage "B" was 50 per cent. larger than "A". Typewriting efficiency was tested in three grades of difficulty: on a memory line; on scientific prose and on nonsense combinations.

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[7] Vernon, M. H., Report No. 34, 1919, Medical Research Committee, London.

[8] Miles, W. R., Carnegie Inst., Washington, Pub. No. 333.

As a result on accuracy, Miles says (p. 69): "If the practical excellence of typewritten material is to be judged on the basis of its freedom from such errors or such groupings of errors as make the contents of the material difficult of understanding, then it must be concluded from this investigation that 21 to 28 grams of alcohol given in a 14 to 22 per cent. solution (dose A) reduces the quality of typewriting about 50 per cent. for a period extending 2 hours after taking the alcohol on a relatively empty stomach, and continues to affect the typewriting unfavorably to the extent of about 25 per cent. in the period from 3 to 4½ hours after the alcohol. The taking of 32 to 42 grams of ethyl alcohol in 150 to 200 cc of liquid (dose B) decreases the excellence of the typewritten copy of easy practice-sentence work about 160 per cent. as an average in the 2 hours after the taking of the beverage, and as much as 90 per cent. even 3 hours after the alcohol is taken."

McDougall and Smith[9] have added a series of experiments which tests accuracy of performance. The machine which they used was a mechanical device having a continuous band of paper-tape about an inch wide on which were distributed irregularly but at equal intervals small red circles. As the red circles passed the window at a uniform rate, they were marked. Among the 1,200 red circles on a tape of six meters' length were 90 blue circles which were not to be marked. As the blue circles passed, the right hand had to be lifted to avoid marking the circle. At the same time the left hand tapped a key attached to a recording pen to show if the key had been tapped.

Four types of errors occurred: (a) A circle was allowed to pass unmarked; (b) a blue circle was marked; (c) an extra dot was inserted between two circles; (d) the circles aimed at were not hit squarely.

To test the effect of alcohol on the accuracy of this operation, a dose varying from 10 to 30 cc of pure alcohol mixed with three parts of water was taken on an empty stomach; one hour later the test was made. McDougall and Smith found after a dose of 10 cc an average increase in the number of errors of 21 per cent., after 15 cc of alcohol an increase of 42 per cent., after 20 cc an average of 39 per cent., and after 25 cc an average of 113 per cent.

CONCLUSIONS

In concluding this paper we may again refer to our original question: What does alcohol do to the body? With increasing knowledge man's answer to this question has undergone great change. During his early experience with distilled spirits man regarded alcohol as a prolonger of life and as a sort of cure-all. He soon learned, however, that excess is injurious. Moreover physicians have found that the wide application of alcohol to disease formerly practiced in medicine is untenable. To-day its use is restricted largely to two types of cases. First, it may be used as a nutritive in certain types of fevers, and secondly it is often employed more for its psychological effect than for its curative effect. Time will tell to what extent these usages can be justified.

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[9] McDougall, Wm., and Smith, M., 1920. Medical Research Council No. 56, London.

Modern experiment has dealt largely with alcohol in so-called moderate doses. From experiments like those on typesetting it early appeared that moderate amounts of alcohol assist in the performance of work. But this has not proved to be the case, for as Vernon, Miles, McDougall and Smith have shown, the work performed is inferior in quality. After Atwater and Benedict proved that the body can oxidize alcohol and the alcohol can be used in work, alcohol was regarded by some as a possible important source of energy. In considering alcohol as a source of energy two phases of the question may be noted: First: We have learned from the studies of Professor Durig on mountain climbing (see Starling, p. 62) that in moderate dosage alcohol can not be used advantageously for hard physical work. Secondly, the amount of alcohol given by Atwater and Benedict (about one half ounce) was a *minimum* dose, a dose which gave no effect of drug action, rather than a so-called *moderate* dose. To define *moderation* in alcohol is a difficult task. If it is true, as recently stated by Starling[10] (p. 174), that "Any dose is immoderate which diminishes a man's efficiency and powers of performing his normal avocations" then we must conclude from the work of Dodge and Benedict, Vernon, Miles and McDougall and Smith that alcohol, even in so-called moderation, may be detrimental to man.

By experience then we have learned that alcohol is not a cure-all; that it can be applied advantageously to but few diseases, and that in excess it is injurious. By experiment we have ascertained that even moderate amounts of alcohol may decrease the activity of a muscle and may militate against precision and accuracy in various types of skilled acts.

We are at present especially ignorant, however, of one phase of the action of alcohol. As might be expected, it is precisely on this point that men are in the widest disagreement. One group holds that alcohol is a real benefit to mankind in that through its use men can get relief from "petty worries." As Starling (*loc. cit.*, p. 175) says, alcohol may be used "to produce the increased pleasure in living." This subjective effect is without doubt the reason for social drinking; for the banquet goes better after inhibitions have been removed. A second group maintains, however, that man should be sportsman enough not to need the aid of alcohol to make the banquet "go"; that he profits by cultivating his natural endowments to this end, and at the same time runs no risk of injury to body and mind. These two positions are subject to direct study, and this question, too, will be solved in time.

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[10] Starling, E. G., 1923. "The Action of Alcohol on Man." London.

NEW HARMONY

By Dr. **DAVID STARR JORDAN**
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and Dr. **AMOS W. BUTLER**
INDIANAPOLIS

The Indiana Academy of Science celebrated from May 12 to 14 the Centennial Anniversary of Western Science in the town where scientific investigation in that region practically began. New Harmony lies in Posey County, the most southern of the 92 counties of Indiana. Posey County occupies the rich and level farming land of the southwest corner of the state, bounded on one side by the Ohio River, on another by the Wabash, the Ohio separating it from Kentucky, the Wabash from Illinois. On the east side, on the Wabash, is the village of New Harmony, with about 1,200 inhabitants, the scene of the great communistic experiment of Robert Owen, who was a prosperous mill owner, well known for his cooperative industrial effort at New Lanark, Scotland. Fertile soil, abundant water, salubrious climate, furnished a favorable setting.

A century and more ago the civilized world began to feel that the age of business competition was passing, and that a new social and industrial era was at hand. This was not the first time nor yet the last when ideal conditions seemed imminent in human relations. Franklin once indicated that if every one would work three hours a day at something useful, poverty would be banished and all men might spend the afternoon of each day and the whole afternoon of life amid the consolations of philosophy, the charms of literature or the delights of social intercourse. In the words of Robert Dale Owen, men "looked forward to the time when riches, because of their superfluity, would cease to be the end and aim of men's thoughts, plotting and lifelong stirring; when the mere possession of wealth would no longer confer distinction any more than does the possession of water, than which there is no property of greater worth."

With the same thought, the geologist, William Maclure, prominent in the Philadelphia Academy of Natural Science, refusing to invest money in Philadelphia, asserted that "land in cities could no longer rise in value. The community system must prevail and in the course of a few years Philadelphia must be deserted and those who live long enough may come back here and see foxes looking out of the windows."

Entranced by these ideas, Robert Owen, of New Lanark in Scotland, successful author of various reforms, came to America to put his conceptions and experiences into practice. With Owen was associated William Maclure, one of the eminent geologists of the day and a friend of scientific men, many of whom he induced to join in a great humanitarian enterprise.

The property at New Harmony was bought by Owen from George Rapp, the head of a celibate German communistic cult, known as the "Economists." These then left Indiana to form a settlement in central Pennsylvania which they named Economy. Under Rapp's rule this experiment was financially successful because it was dominated by a single will. Both his ventures, in Indiana and in Pennsylvania, were ideal Theocracies, ruled autocratically under divine right. According to Rapp an angel appeared at his bedside every morning to direct what each member of the community should do each day.

At the foundation of New Harmony,

Maclure and others came down the Ohio River on a boat named "The Philanthropist." This became locally famous as "The Boatload of Knowledge." It contained all the men of science whom the geologist was able to reach and influence. His plan was to build up in this community a School of Industry which should teach the "Conquest of Nature." Farmers should rise above the status of "tillers of the soil" to leading the land to do its best. A magazine was founded, called "The Disseminator of Useful Knowledge, containing Hints to the Youth of the United States from the School of Industry." In "The Disseminator" appeared from time to time valuable articles from naturalist members of the community.

Thomas Say, one of the founders of the Philadelphia Academy of Natural Science, formerly a member of Long's Expedition to the Rocky Mountains, wrote learnedly on insects, birds and shells. Another pioneer naturalist, the French artist, Charles A. LeSueur, also came to New Harmony with the "Boatload of Knowledge." A friend of Cuvier, with an established reputation as naturalist and artist, he had been around the world on La Perousé's celebrated voyage. In the drawing and painting of animals he showed rare skill, and his woodcuts of the fishes of the Great Lakes are among the most lifelike ever published. It was he who painted the drop-curtain of the Community Hall. This represented Niagara Falls with "the other marvel of the New World," the rattlesnake, coiled beside it. Richard Owen was a favorite with LeSueur and once told Dr. Jordan how he used to wade barefoot in the bayous of the Wabash to gather mussel shells for the gifted naturalist. Three of the sons of Robert Owen—David Dale Owen, Robert Dale Owen and Richard Owen—were each highly gifted, David and Richard as geologists, Robert in literature and the humanities. Robert Dale Owen was long and favorably known as a charming writer, one of the group of essayists who early gave to the *Atlantic Monthly* its high literary character. As a member of the Indiana Legislature he had a large part in shaping the public school system of the state. David Dale, the second son, and Richard, the youngest of this remarkable family, were intimately associated throughout their lives. David, afterward the first United States geologist, was especially interested in fossils and minerals. He classified the great collection left by Maclure, which, with his own extensive accumulations, afterward formed the Owen Museum (of 85,000 specimens) of Indiana University, one of the largest displays of Paleozoic fossils in America until its partial destruction by fire in 1883. In 1886 a large part of this collection was sent to the United States National Museum, in return for the re-identification and restoration of labels lost or destroyed by the fire. The only daughter of Robert Owen who came to America, Jane Dale Owen, a woman of much ability and of considerable scientific knowledge, married Robert H. Fauntleroy, astronomer and meteorologist in the service of the United States government. Upon his death he was succeeded by his son-in-law, Professor George Davidson, the well-known astronomer of the United States Coast Survey, who took up his abode for a time in New Harmony.

The New Harmony school-master, Dr. Joseph Neef, was a blunt, plain spoken, honest man, a great favorite with his pupils. An Alsatian by birth, he had been priest, soldier and at the same time a mathematician of high ability—for a while also, associate of Pestalozzi in his famous school at Yverdon, Switzerland. Pestalozzi once commended him as "an earnest, manly worker, who did not disdain to occupy himself with the elements of science.'' Maclure met Neef in Paris, and brought him over to America. ''It is my highest ambition,'' said Neef, ''to be a country school teacher amidst a hardy, vigorous community.'' His two daughters both married Owens, the one David Dale, the other, Richard. Another who came on ''The Philanthropist'' was the Dutch scientist, Dr. Gerard Troost, who remained for some time, becoming state geologist of Tennessee.

Richard Owen was professor of natural science in Indiana University from 1863 to 1879, where Mr. Butler was one of his pupils. Dr. Jordan was chosen as Richard Owen's successor. Owen was a man of broad scholarship and large sympathies as well as of courtly manners. Dr. Jordan gave a lecture in New Harmony with Dr. Owen in the chair. He was then very old and heard not a word which was said, but by watching the faces of the audience he was able to exhibit every appropriate shade of feeling for which the address seemed to call.

Many distinguished visitors came to New Harmony, among them Sir Charles Lyell, greatest of all geologists, who was once a guest of the Owens. Constantine Rafinesque, eccentric and ultra individualist, also passed that way ''on foot, with a bundle of plants under which a peddler might groan.''

The New Harmony experiment, based on Communism, lasted but a short time. Its failure was in its economics; its successes in the study of nature. Some blamed Owen himself for his refusal to deed to the Community all its property. He chose to wait to see how it turned out. Common opinion asserts that it had ''too many managers and too few workers.'' Common ownership requires community of spirit. Drones and workers can not have equal access to honey cells, a fact that has many times been demonstrated. But from another point of view —that of common life among free spirits—''Gemeingeist unter freien Geistern''—the episode must be reckoned a great success. It marked the advent in the Middle West of serious work in science. More than any others, Owen and his sons were advance leaders in the progress. The beginning of the United States Geological Survey was the work of David Dale Owen, and till near the time of the Civil War, its actual headquarters were at New Harmony. The Brookville Natural History Society, founded by Amos W. Butler in 1881, caught its first inspiration from Owen and Say and it was the chief influence in the founding of the Indiana Academy of Science in 1885.

After the failure of the Owen venture New Harmony continued as a center of scientific activity. The United States Geological Survey, the work of the United States Coast and Geodetic Survey Meteorological Records and the libraries begun by William Maclure in New Harmony and extended throughout the state. It was a training school for young geologists. Among those who worked there were Edward T. Cox, state geologist of Indiana; J. G. Norwood and A. H. Northern, state geologists of Illinois; B. F. Shumard, state geologist of Texas; Dr. Robert Peters, Dr. Joseph Leidy, F. B. Meek and Leo Lesquereux.

It is fortunate that so much has been preserved for a century, that the Indiana Academy of Science has felt the urge to pay honor to the memory of these pioneers. For more and more, New Harmony is becoming a place of pilgrimage for the social scientist, the educator, the historian, the student of the natural and of the physical sciences and the tourist. A beaten pathway has been made to the door of New Harmony.

THE PROGRESS OF SCIENCE

EDITED BY EDWIN E. SLOSSON

Director of Science Service

THE SECRET OF SYNTHETIC PETROLEUM

CURRENT discussion in the newspapers of the combination of the Standard Oil Company of New Jersey with the German Dye Trust for the production of synthetic petroleum has made the American public realize for the first time that constructive chemistry has reached a point where it is to be taken seriously in this field. We had heard for some time rumors that the Germans were experimenting in methods for making artificial motor fuel, but then we should expect German scientists to fool around with such a visionary idea. We could understand also why the British, since they had no oil of their own, should take an interest—even a financial interest—in such projects.

But why should we, when our petroleum output had reached an unprecedented height and still had not passed its long-predicted peak, when the oil was pouring from the ground faster than it could be barreled and sold, when the Congress is being called upon to put a stopper on our overflowing wells—why should we concern ourselves with the development of a difficult, expensive and untried process for converting coal into coal oil? A patent for the making of gasoline and other things from coal was among the mass of German patents taken over by the Alien Property Custodian when we entered the war and placed in the hands of the Chemical Foundation for the employment of any true-blue American, but nobody cared to call for it.

But now when we see that the very men who are most active in handling natural petroleum are acquiring the rights for making its synthetic competitor, our papers are full of wonder-why editorials. Two kinds of answers are prominent: first, that Standard Oil is preparing for the future when the fluid fossil fuel that we are drawing upon so unwisely and using so wastefully will begin to run out; second, that the process concerned has an immediate application to the working up of heavy oil residues and distillates, asphalts and tars, into gasoline and other valuable products such as alcohols.

Which of these surmises is the main object can not be determined by the public since the particular process to be employed is still a secret. It is known to be based upon the method for the liquefaction of coal developed by Dr. Friedrich Bergius, of Heidelberg, but it is said to involve the use of some unknown catalyst. "Catalyst" is the name given by chemists to a substance which promotes by its mere presence the desired reaction. In this case, for instance, the catalyst may serve to facilitate the joining of the carbon atoms of the coal with the hydrogen atoms from water to form gasoline, somewhat as the brakeman on a train couples together the cars. The original Bergius process was distinguished from its rivals by dispensing with any catalyst and forming the union between carbon and hydrogen by employing high temperature and pressure alone. But apparently for certain purposes that we can only surmise some catalyst is found a useful aid.

The first step in the effort to solve the mystery of the unexplained catalyst is to make a search of the patents recently applied for by the I. G., the combine of chemical industries commonly called the German Dye Trust. One of the catalysts specified is sulphur. Now sulphur is

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THE RECENT ERUPTION OF MOUNT VESUVIUS

SMOKE AND LAVA FROM THE CRATER OF THE VOLCANO DURING A RECRUDESCENCE OF THE RECENT ERUPTION.

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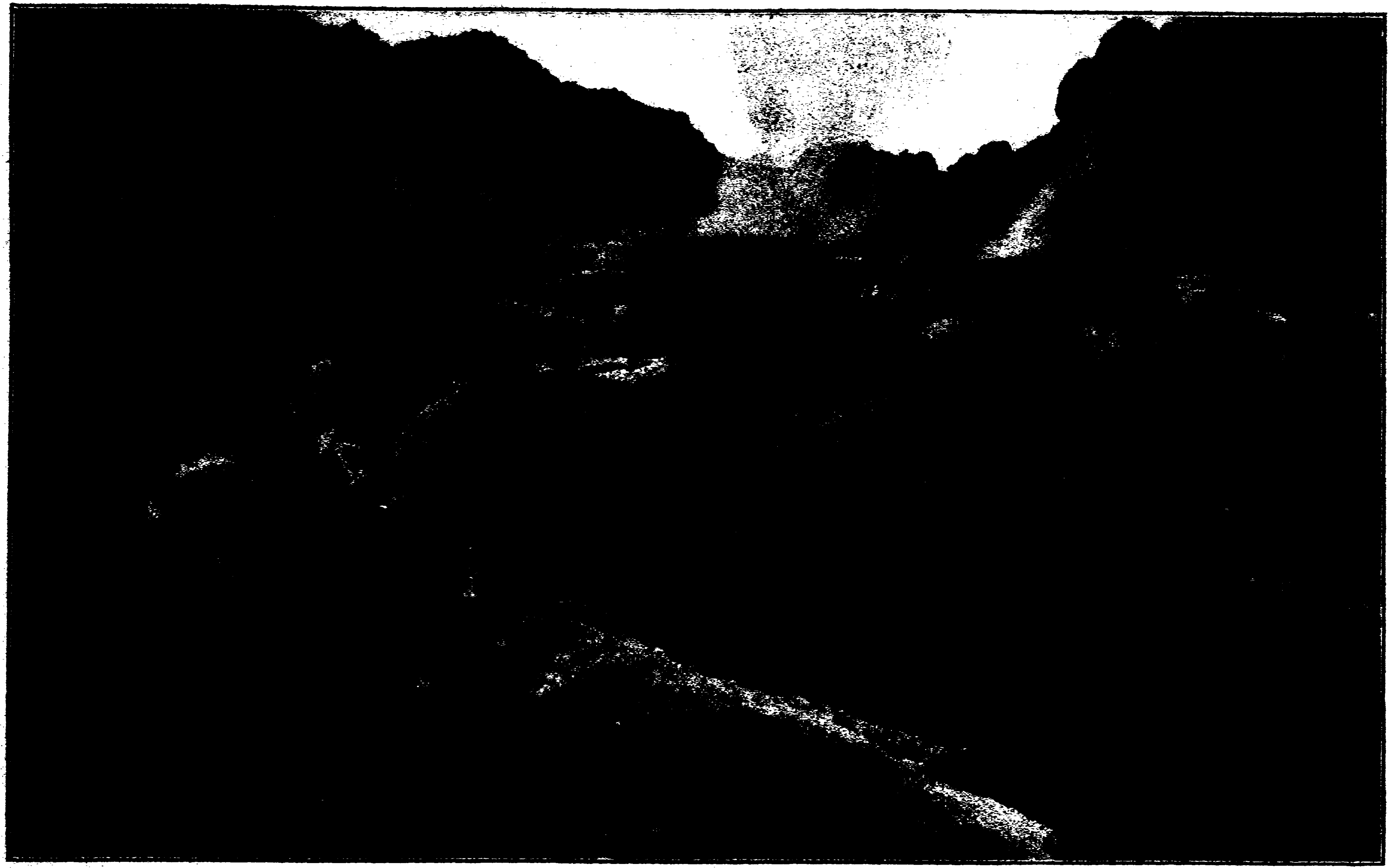
PROFESSOR ALESSANDRO MALLADRA

DIRECTOR OF THE VESUVIUS OBSERVATORY, IS SEEN IN FRONT OF HIS HOUSE WHICH STANDS AT THE FOOT OF MOUNT VESUVIUS; FROM THERE HE OBSERVES AND REPORTS THE ACTIVITIES.

found frequently in coal and oil where it is regarded as objectionable. For many years the petroleums of some of our richest fields were rejected as unusable because of their sulphurous smell until finally a way was found to eliminate the obnoxious ingredient. It would be funny if the element that the chemists worked so hard to get rid of should turn out to be so useful that it is added where wanting. It might be added in the unpleasantly familiar form of hydrogen sulphide which would carry the necessary hydrogen as well.

The high cost of free hydrogen has been regarded by outsiders as an obstacle to the process, but it has been recently revealed that this element may be introduced in the form of steam, or of methane, which occurs in our natural gas or may be made artificially.

Among other catalysts mentioned in the I. G. patents are compounds of nitrogen. Now, nitrogen is also a common compound of coal, or it might be introduced in the form of some synthetic compound manufactured from air. Other catalytic agents specified the rare



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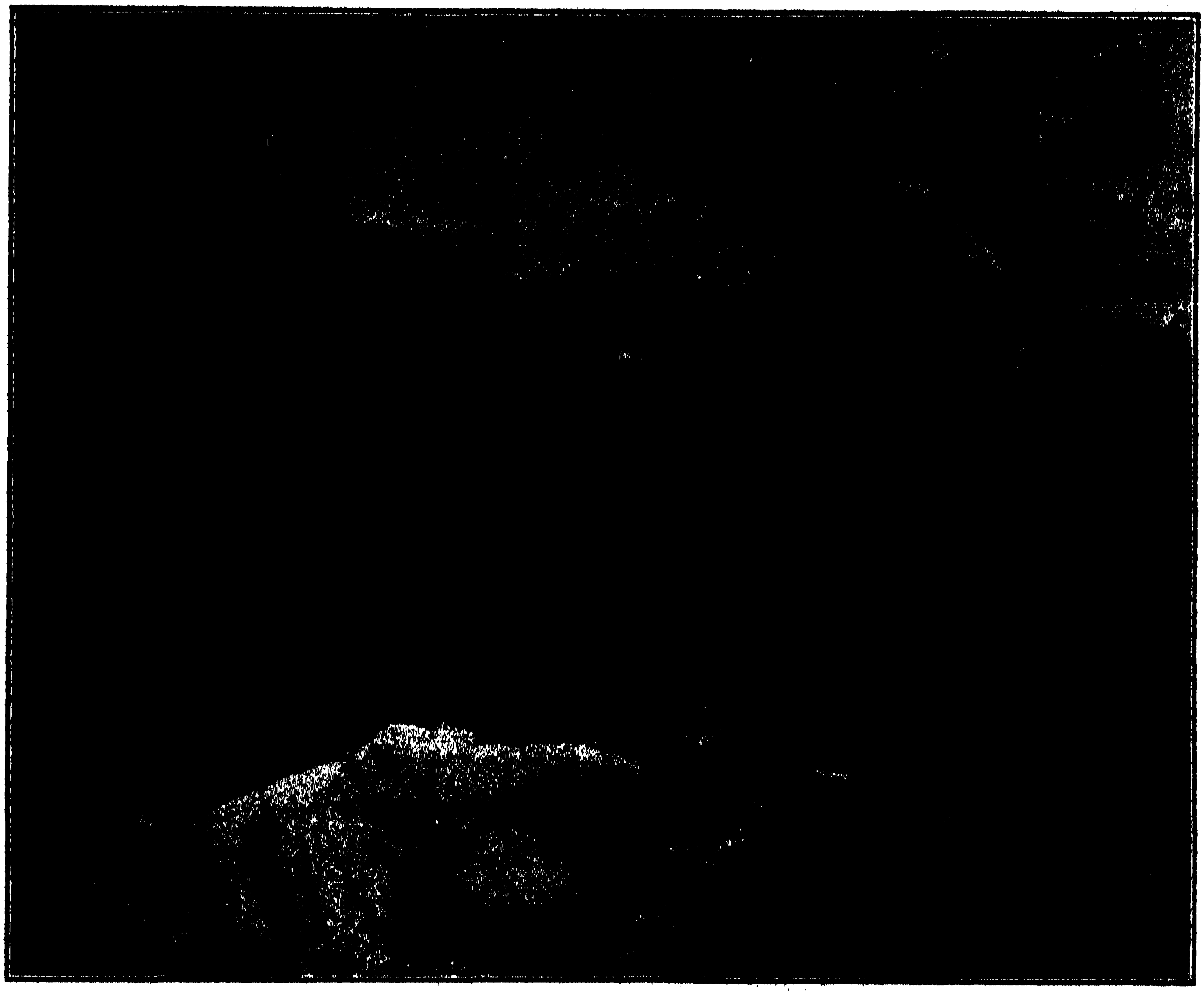
THE RECENT ERUPTION OF MOUNT VESUVIUS

THE NORTHEASTERN SECTOR OF THE CRATER OF THE VOLCANO AFTER THE RECENT ERUPTION, SHOWING THE NEW CAVITIES FROM WHICH THE LAVA FLOODS WERE EJECTED.



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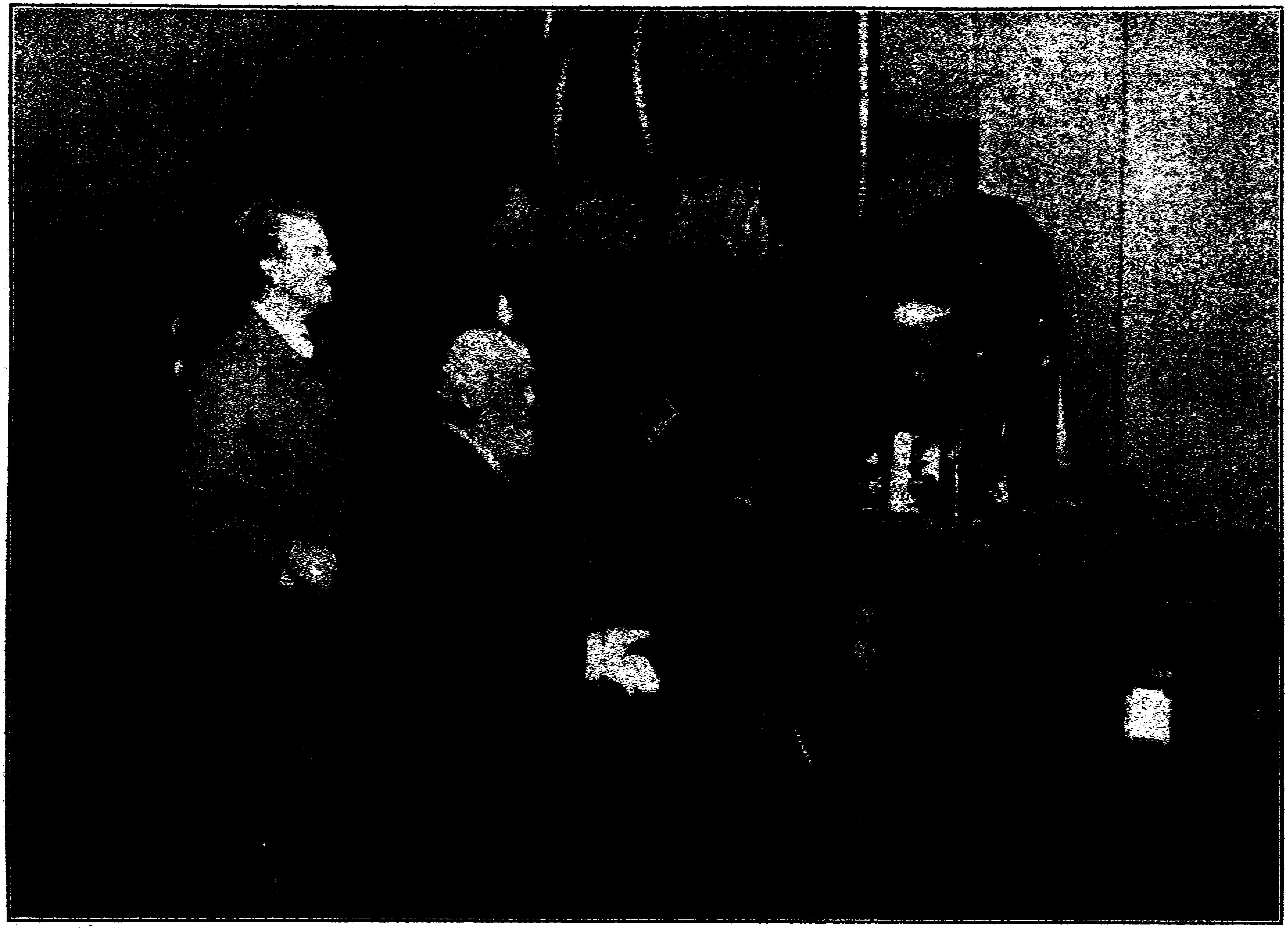
PROFESSOR ALFONSO SENNINO

STUDYING THE RECENT ERUPTION OF VESUVIUS AT THE SIDE OF THE CRATER.

—or until recently unfamiliar—metals molybdenum, tungsten and chromium, and their compounds, and so many other substances that it is impossible to guess which is to be most employed.

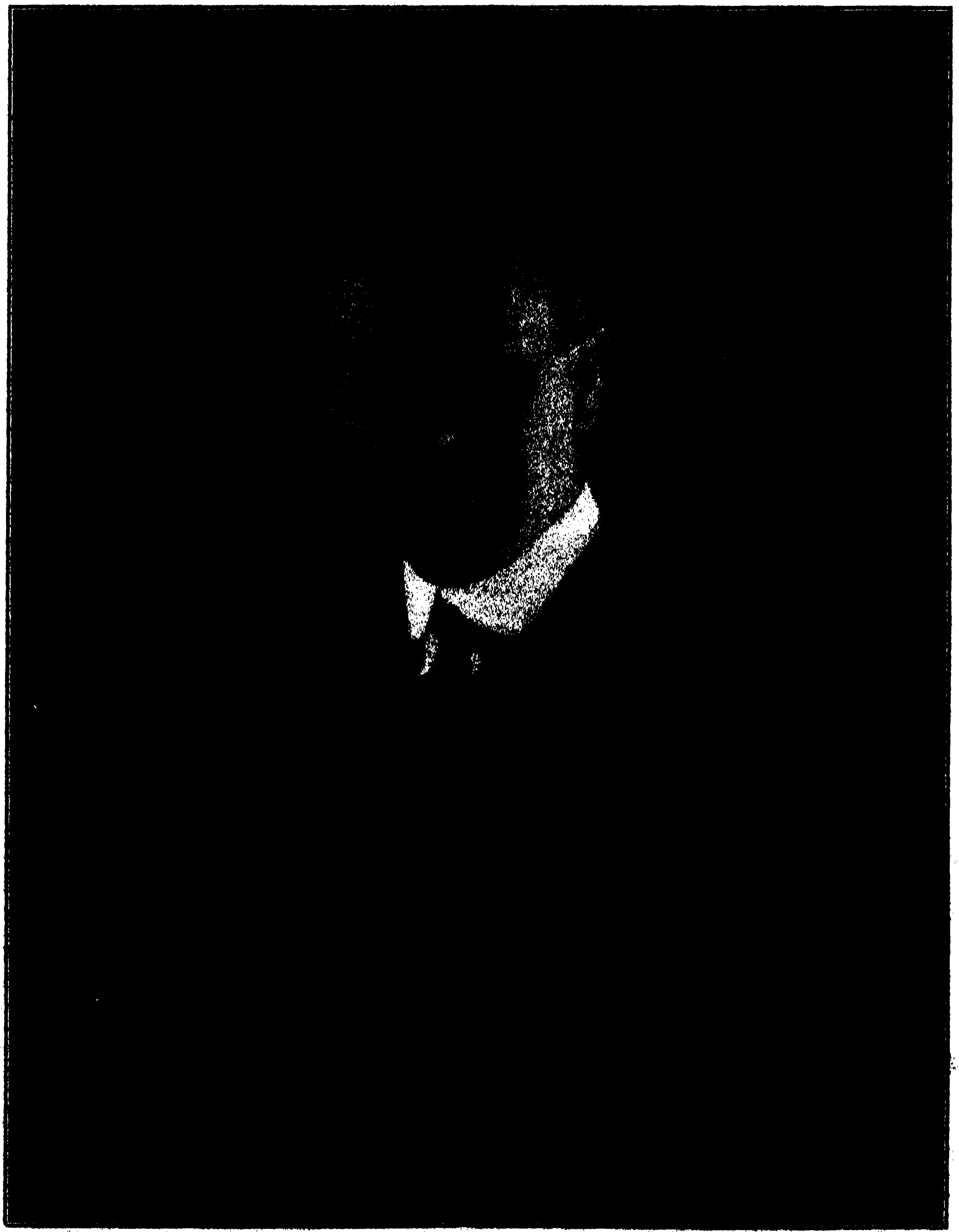
Dr. Bergius explained his process for the transformation of coal into oil before the Pittsburgh Conference on Bituminous Coal with remarkable freedom and frankness, but it was noticed by the audience that he said little or nothing about its catalytic possibilities. In the discussions of the conference several of the experts present tried to elicit his views on this crucial point. His final answer is worth quoting in view of the public interest now aroused on the subject: I only wish to have a word to avoid misunderstanding. I want to say that certainly catalytic action occurs also in coal hydrogenation. Yesterday the time was too short to give every detail on this complicated reaction, but I think I remarked at one point that there is catalytic action too, and we found that there are a lot of things, a lot of material, which helps catalytic action.

And he specified among the lot of things which modify the products, favorably or unfavorably, the composition of the ash, the presence of sulphur, iron oxide, alkaline compounds, compounds of the carbolic-acid group, and a German synthetic substance known as tetraline, made from naphthalene (well known as mothballs) by the addition of hydrogen.



SIR OLIVER LODGE

THE DISTINGUISHED BRITISH PHYSICIST, AT THE RECENT LEEDS MEETING OF THE BRITISH ASSOCIATION EXAMINING THE APPARATUS INVENTED BY J. L. BAIRD FOR THE TRANSMISSION OF PICTURES OVER TELEPHONE WIRES.



—*Photograph by the courtesy of Dr. Frank M. Chapman*

LOUIS AGASSIZ FUERTES

IN WHOSE DEATH, AT HIS HOME AT ITHACA, ORNITHOLOGY AND ORNITHOLOGICAL ILLUSTRATION HAS LOST A DISTINGUISHED LEADER.

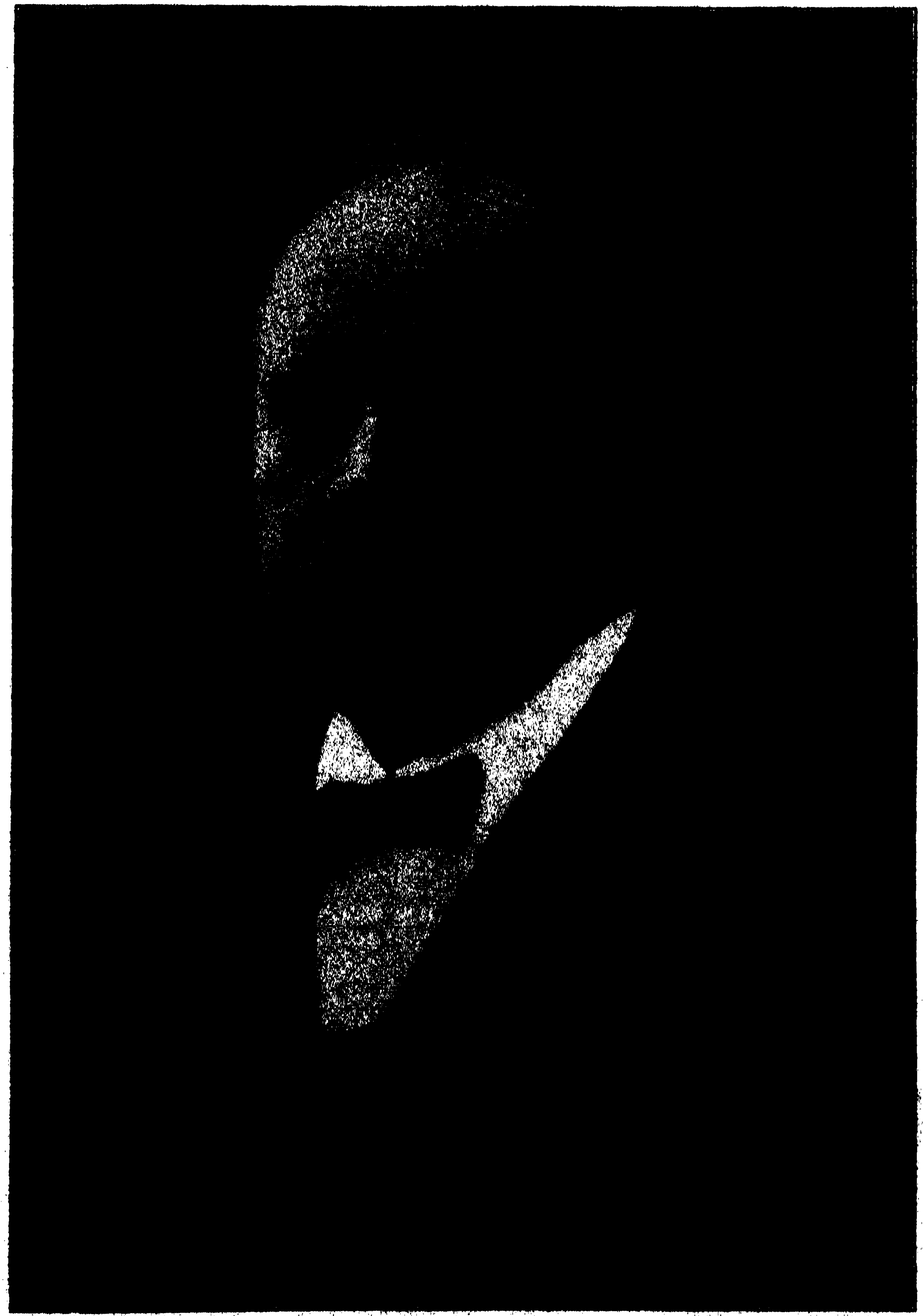
SVANTE AUGUST ARRHENIUS

THE death of Professor Arrhenius, which occurred at Stockholm on October 2, deprives physical science of its most remarkable leader. Arrhenius was born near Upsala in 1859, and first leaped into fame when, as a young man of twenty-five, he published his doctor's dissertation entitled, "Researches on the Conductivity of Electrolytes." This thesis contained the first guarded indication of what is known as the ionization theory, a detailed elaboration of which followed a few years later. According to the ionization theory of Arrhenius, a salt such as sodium chloride is largely broken up in aqueous solution into electrically charged ions, *e.g.*, sodium ions and chlorine ions, and this simple assumption has served as the basis for astonishing advances in our knowledge of the physical chemistry of solutions during the last forty years. Arrhenius encountered, however, most violent opposition from many quarters, and only through the enthusiastic support of Ostwald did his theory gain general acceptance. Oddly enough, while the ideas of Arrhenius were long regarded as entirely too revolutionary by many chemists, the existence of free sodium ions and free chlorine ions in the same solution being considered an impossibility even by his own professors, more recent advances have led to the conclusion that Arrhenius really did not go far enough in his assumptions, the present conception of a salt solution involving complete, rather than partial, ionization.

Through the influence of Ostwald, the young Arrhenius was awarded a traveling fellowship, under which he worked in the chief laboratories of Europe for several years, returning to Stockholm as a lecturer in the Högskola. The intense patriotism of Arrhenius held him in this position (which corresponded more closely to a professorship in a university than to its actual title) for many years, during which he refused a number of attractive offers from other countries, especially from Germany. Finally he was appointed director of the Nobel Institute for Physical Chemistry, pleasantly situated in the suburbs of Stockholm, and there he was enabled to continue free and uninterrupted research work for many years, surrounded by a small but eager band of advanced students.

Arrhenius was one of the few men who did not find it necessary to specialize; his scientific interests extended into the most diverse fields. His fame as a physical chemist, however, will probably always overshadow the researches which he carried out in biochemistry, astronomy, anthropology and cosmology. Of all recent workers, he most deserved the title of "universal scientist," not only for his broad viewpoint, but also for the warm personal contacts which his genial nature ensured him in his extensive travels. The honors conferred upon him throughout his career were innumerable. He was a Nobel prize winner, a foreign member of the Royal Society, and the recipient of practically every distinction that could be bestowed upon a scientist. In the course of several visits to America, he delivered a series of lectures at the University of California and at Yale University, and he was awarded the Willard Gibbs Medal of the Chicago Section of the American Chemical Society. The Silliman Lectures which he gave at New Haven were later published in book form under the title, "Theories of Solution." Other notable volumes from his pen include "A Text-book in Electrochemistry," "Worlds in the Making" and "Chemistry in Modern Life."

JAMES KENDALL



SVANTE AUGUST ARRHENIUS

EXCAVATIONS AT POMPEII

A MARVELOUS bronze resurrection from the deadening ashes that covered the city of Pompeii has just been officially announced by Professor A. Maiuri. Unearthing this statue in a house in the Street of Abundance is like having the dead come back to life after being buried for eighteen hundred years.

The Street of Abundance of Pompeii has been for some four or five years past the most attractive spot in that ancient Roman town which was buried under the ashes from the eruption of Vesuvius in 79 A. D. Excavations along this street have held the best pay dirt—as it were—of any of the digs in Pompeii. A huge wooden gate shuts the tourists away from this street. It is quite possible to obtain a special pass by making application to the proper authority, though no cameras are allowed. The excavation has been done slowly and carefully on a specified plan. They dug the ashes out of the street first; now they are taking the houses one at a time and cleaning them out.

The most exciting moment of this century at Pompeii came a few months ago. The excavators dug the ashes out of the doorway of the house, Street of Abundance, No. 11, and started clearing away in the *atrium*, which was the reception room. Nothing much was found. Then they dug ahead into the next room, the *tablinum*, which was a sort of office of the man of the house. At the rear of the room a pilaster, on one side of the door leading back into the second atrium, stuck up above the ashes. As they dug away the ashes, suddenly, just in front of the pilaster, a magnificent bronze head came into sight. It was the head of a young man with almost a Greek profile, with firm lips and with the most splendid head of wavy hair confined by a fillet band. The young man was looking slightly downward and to the right.

By this time all Italy was in a ferment because the news had spread that a magnificent bronze statue, and best of all an unbroken and unmutilated one, was rising from the dead past of Pompeii. Perhaps it would turn out to be an original of the best period from the atelier of a famous master!

Speculation was rife because of the position of the arms of the new bronze youth. His left arm hung easily at his side, except that the muscles of the upper arm seemed taut. The right forearm went straight out from the elbow, which was advanced a bit from the body, and the strangely closed right hand seemed to have held something. All sorts of guesses were made, but none of them was right. When the entire statue stood free, it was a nude bronze youth fifty-four inches high, standing easily with his weight on his straight right leg. Both feet were firmly planted on a circular bronze base.

In the ashes near the base of the statue were found two artistic pieces of bronze, alike except in the length of the stem pieces. From the bronze bud spread two bronze tendrils which looped gracefully away one to either side, each one curling under and over, with open flowers at the ends of the curls. On the tendrils of each bronze plant were three bronze holders.

The long stem and plant was placed in the hanging left hand of the bronze statue and the short one in his extended right hand, and lo! the transformation. The beautiful bronze youth was a candelabrum, a "light bearer." What a magnificent and decorative way to light the tablinum of the master of this house, number 11, in the Street of Abundance!

R. V. D. MAGOFFIN

THE SCIENTIFIC MONTHLY

DECEMBER, 1927

SMELL AND TASTE AND THEIR APPLICATIONS

By Dr. N. E. McINDOO
WASHINGTON, D. C.

IS THERE A SCIENCE OF SMELL OR OF TASTE?

THE late Alexander Graham Bell, when once consulted about the physico-chemical possibilities of odors, remarked that an odor had already made one man famous. He asked who was ready to evolve a new science, by measuring or reflecting a smell. He said in part:

> Have you an ambition to found a new science? Why not measure a smell? Can you measure the difference between one kind of smell and another? Until you can measure their likenesses and differences you can have no science of odor. Find out what an odor is—whether it is an emanation, and therefore subject to being weighed, or a vibration, and therefore capable of being reflected. Odors are becoming more and more important in the world of scientific experiments and in medicine—and the need of more knowledge will bring more knowledge, as surely as the sun shines.

Regardless of the above admonition that we do not yet have a science of smell, Kenneth, a Scottish professor in the University of Edinburgh, has listed 1,000 references on "Osmics: The Science of Smell," and makes the following remarks:

> Smells are surer than sounds to make the heart-strings crack, yet, owing to a lack of training, one is not always aware of the fact that one lives in a world of smell as well as in a world of form, color and sound. However, the knowledge of the organs and the sense of smell, and of odorous substances, is recorded in a voluminous and widely scattered literature. Some day, perhaps, a special Institute of Osmics will be established, where research could be coordinated. The staff would comprise at least a physiologist, psychologist, chemist, zoologist, botanist, anthropologist, pathologist, rhinologist and statistician, and would also require the services of an embryologist, geneticist and a paleontologist.

What next! No wonder so little has been accomplished on this subject, if in order to obtain results such an extensive collaboration is really necessary! Yet when we carefully examine our records we are convinced that more cooperation between the various groups of scientists interested in this subject is absolutely necessary before we can actually found a new science as outlined by Dr. Bell.

According to Kenneth:

> Briefly, osmics is a science of the stimuli, organs and the sense of smell. It is evident, therefore, that this area of science is fundamentally a rendezvous of chemistry, physics and biology in the widest sense.

The word "osmics" comes from a Greek word, meaning odor; and Kenneth is so enthusiastic about encouraging the foundation of a science of smell, which really involves the deepest studies in botany, zoology, chemistry and physics, that he imagines that the results obtained will aid research on the nature of matter.

Another enthusiastic scientist, a chemist, who is encouraging research in the sense of smell, is Hendrick. He says:

> It is remarkable how intimate the sense of smell is, how much it tells us, and how largely it affects consciousness on the one hand, and how we scorn consideration of it on the other. It is the Cinderella of our organs of sense. Whether it was some sainted anchorite, or other enthusiast of imagination and influence, who found the use of the human nose to be dangerous to the soul, we do not know, but in some way or other the conscious exercise of the nose became taboo, and this has entered into the folk-ways. It has ceased to be a sin, but it remains an impolite subject.
>
> The Arabs in their days of glory were not ashamed of their noses, and they planted scented gardens, wonderfully devised, so that he who walked through them, or whiled away an hour there, might rejoice in a cultured delight in odor. They were so arranged that at the entrance the olfactory sense would be struck by a pervading and strong smell, not necessarily of a pleasant nature. From this the path would lead gradually through less coarse fragrances to those more delicate until, at the end, there would be reached an odor of exquisite quality which only the cultured nose could appreciate.
>
> Just think what we owe to our eyes and ears! Through them we gain nearly all of our knowledge. They are trained so that by them we read books and hear speeches, we note anger, deceit, joy, love; by sight and hearing we try to guess faithfulness and malice; in fact, through these two senses we draw the substance of our information. And yet we are said to have five senses. Neither touch nor hearing nor sight is within the scope of this paper, and taste is a limited sense, alive only to sweet, sour, bitter and a few simple nerve-reactions. Owing to the taboo of smell we have credited to taste most of those olfactory processes which we have cultivated. It is smell of food that we enjoy while we are eating it; it is the bouquet of a wine that gives it its merit. We call it the taste, but it is chiefly the smell. It is nearly impossible, for instance, to distinguish between what we call the taste of cinnamon and that of cloves if we hold our noses.

The theories of smell and taste, as given, are very vague, and, in comparison to sight and hearing, very little fundamental work has been done on them. In this respect we are still living in the Dark Ages, and have not progressed much since the "glorious" days of the Arabs. Good work has been done, but not enough; and enough will not be done till there obtains a lively and wholesome curiosity about these two neglected senses, which in reality must be studied together, for they can not be sharply separated.

On the other hand, consider what illuminating results are now available from researches in some of the other senses. To illustrate the comparative attention devoted to the different senses, one needs only to open a book of reference, such as the Encyclopædia Britannica. In the last edition of this work, dated 1926, over thirty-two pages are devoted to sound, seventeen and a half to light, and four to touch, but only a page and a half each to smell and taste. The authors of this storehouse of knowledge have either carelessly overlooked the recent information on all the five special senses, except sound, or they consider it of too little merit to be published in the 1922 and 1926 supplements. As the World War aroused a lively interest in sound-detecting devices, ten pages about sound have been added in the last two supplements. Light has been ignored, although the subject of illuminating devices, which does not belong to our discussion of senses, has been brought up to date. One is not surprised to know that the part played by smell in this war has been omitted, for information on this topic is widely scattered and is of less importance than that about the part played by sound and light.

Speaking about the senses, how many do we have? Every one knows about the five special ones, and many of us are aware that we have other senses, called the general senses but how many? Herrick tells us that we have, in reality, more than twenty different senses. Hearing, sight and touch are called the physical senses, and the first two are truly measurable, because their stimuli —sound waves and light waves—have

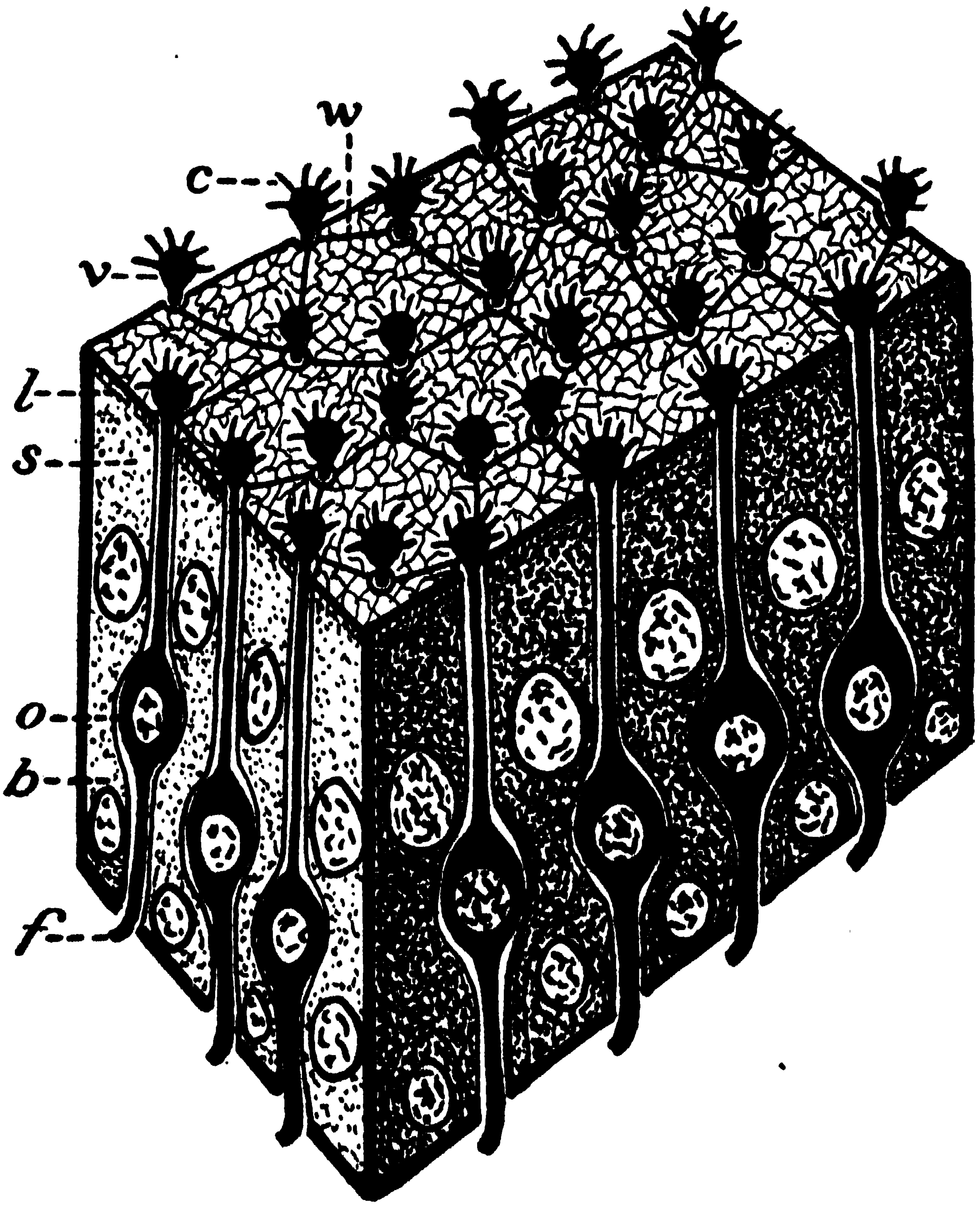


FIG. 1. DIAGRAM OF A BLOCK FROM THE OLFACTORY MUCOUS MEMBRANE OF A KITTEN

SHOWING IN SECTION AND PERSPECTIVE THE FOLLOWING: BASAL CELLS (*b*), OLFACTORY CILIA (*o*), NERVE FIBERS (*f*), LIMITING MEMBRANE (*l*), OLFACTORY CELLS (*o*), SUPPORTING CELLS (*s*), OLFACTORY VESICLES (*v*), AND WALLS (*w*) OF THE FIVE- AND SIX-SIDED SUPPORTING CELLS FROM A SURFACE VIEW. THE OLFACTORY VESICLES AND CILIA, WHICH ARE EMBEDDED IN AND SUPPORTED BY AN OUTER SEMIFLUID (NOT SHOWN IN DRAWING), ARE THE TRUE RECEPTORS OF SMELL. (REDRAWN FROM VAN DER STRICHT'S PHOTOMICROGRAPHS AND FIGURE 36, THE LATTER IN HERRICK'S BOOK.)

been accurately measured and analyzed. As a result of all the thorough study of their stimuli, new worlds have been opened to us; in sound, by the use of the telegraph, telephone, microphone and radio; and in light, by the microscope, telescope, photographic camera and moving picture machine, and by bringing to our aid ultra-violet rays, X-rays and radium. In the light of all this exact knowledge, are we not justified in calling hearing and sight true sciences? But how about smell and taste? We call them chemical senses, because chemicals in one form or another serve as their stimuli. Un-

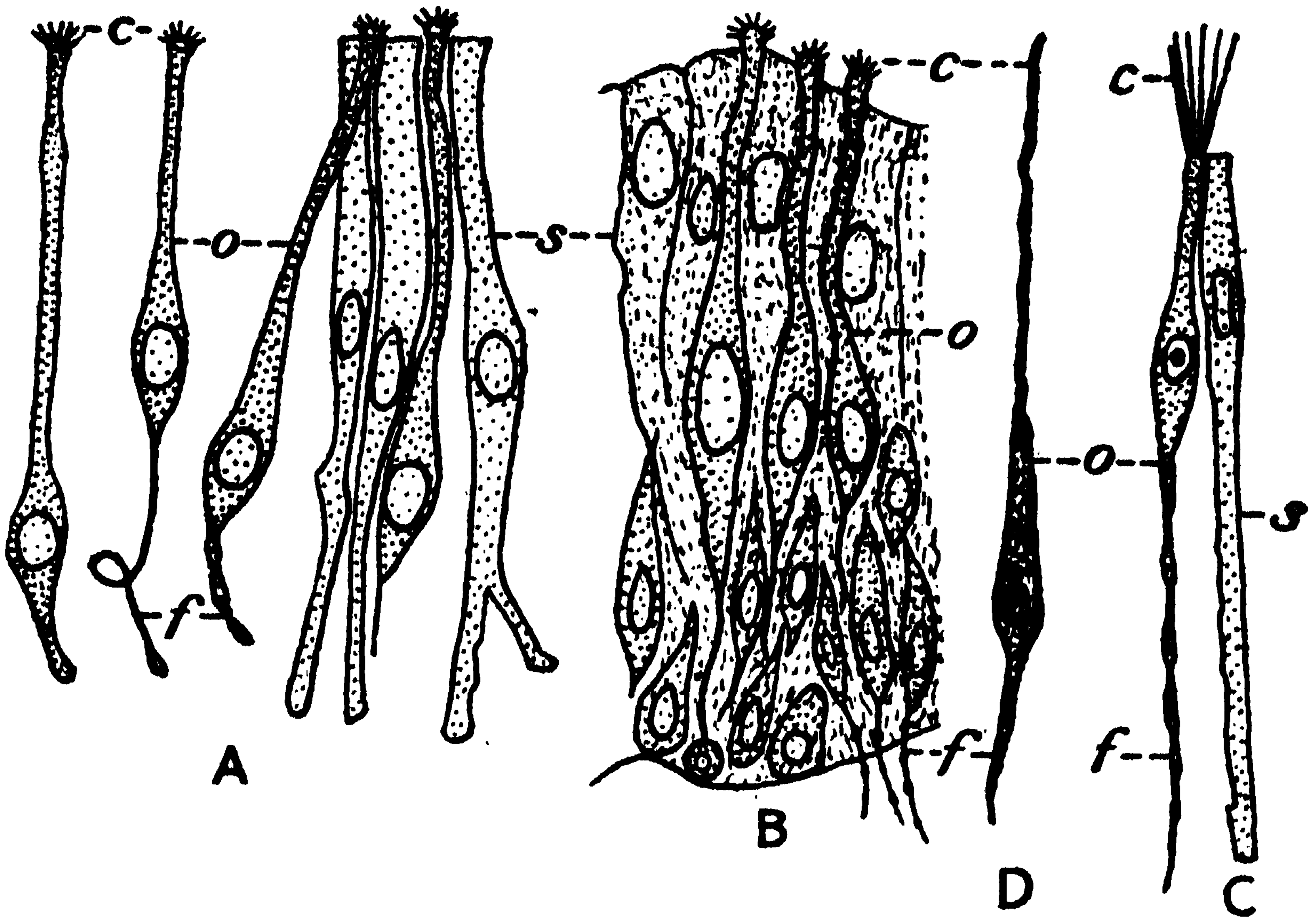


FIG. 2. OLFACTORY CELLS

Olfactory cells (*o*) and their cilia (*c*), and their supporting cells (*s*), from Parker. A, from man (after von Brunn); B, from pig (after Alcock); C, from frog (after Schultze), and D, from a fish (after Jagodowsk).

fortunately, however, the character of this stimulation has as yet defied thorough analysis and we have not learned how to weigh or measure its extent or intensity. It can not be said, therefore, that there is a true science of smell or of taste.

When we consider the uses of smell in connection with food-getting and recognition among animals; when we appreciate how a knowledge of smell and taste in noxious insects aids us in our efforts to control them, and when we think of our own uses of these senses in medicine, perfumery and esthetics, and of the importance to our digestion and health of using them aright, we must realize that taste and smell, particularly the latter, should be more seriously studied. We need the information to be gained in this way. It can be used to our great advantage.

Uses of Smell and Taste in Man

It is well known that appetizing odors and pleasant tastes make the mouth "water" by stimulating the salivary glands. This is brought about by one of Nature's reflex mechanisms, the purpose of which, in this case, is to welcome food to the mouth and begin its digestion there before it is carried to the stomach. Physiologists tell us that what is true for the salivary glands is equally true for the gastric glands in the stomach, and that the latter are fully as susceptible to gentle suggestions from the olfactory organs. It has been shown experimentally that smell and taste bring about the first processes in digestion. Niles says:

> Let us not, therefore, deem unimportant this humble faculty of smell, which, though modest, is always alert and discriminating, and whose influence over the whole digestive system is becoming more and more appreciated.

Disagreeable odors, from the viewpoint of sanitation and the problem of eliminating them, cause the public health officer much concern. There is a wide-spread belief that foul-smelling odors cause disease. This is not necessarily so, for to-day we can not ascribe any known disease to odor. The sources of bad odors, nevertheless, may become breeding places for germ-carrying organisms, and of course these require investigation. Then, too, although bad odors from a cesspool do not necessarily result in organic disease and its attendant physical suffering to those exposed to them, they will cause mental suffering unless the nuisance is soon abated, and often this is worse.

Fumes emitted on a large scale from fermenting and putrefying substances have been reported, in certain cases in France, as injurious to health. When we are dealing with poisonous gases, some of which are odorous, the results on health are sometimes serious and even fatal. Other gases, not necessarily fatal or even dangerous in themselves, sometimes serve as warnings of danger from similar sources. A smell of sewer gas may suggest a polluted water supply, and the odor of coal gas may suggest the presence of the inodorous carbon monoxide, which often proves fatal in closed garages and elsewhere. It has been found advisable to add odorous impurities to our manufactured illuminating gas as a safeguard against gas poisoning through carelessness. It is therefore literally true that our lives are often saved by means of our noses.

Odors are often put to various industrial uses, as in the detection of leaks in boilers and pipe lines. For this purpose the oils of peppermint and wintergreen are generally used, mixed with water or air, and then forced through the pipes and boilers; then by smelling at the cracks and joints, leaks can easily be located. A more accurate method is to use catnip oil and then to let a cat locate the leak. Furthermore, experiments have been conducted in the use of odors as warning signs in mines.

In the practice of medicine the physician is using his nose more and more as an aid in diagnosis and medical writers tell us that, if for no other reason, the sense of smell should be cultivated for this purpose. Certain diseases have characteristic smells, and the sense of smell may with good reason be considered of medico-legal importance.

Bacteriologists use their noses in detecting the characteristic odors of cer-

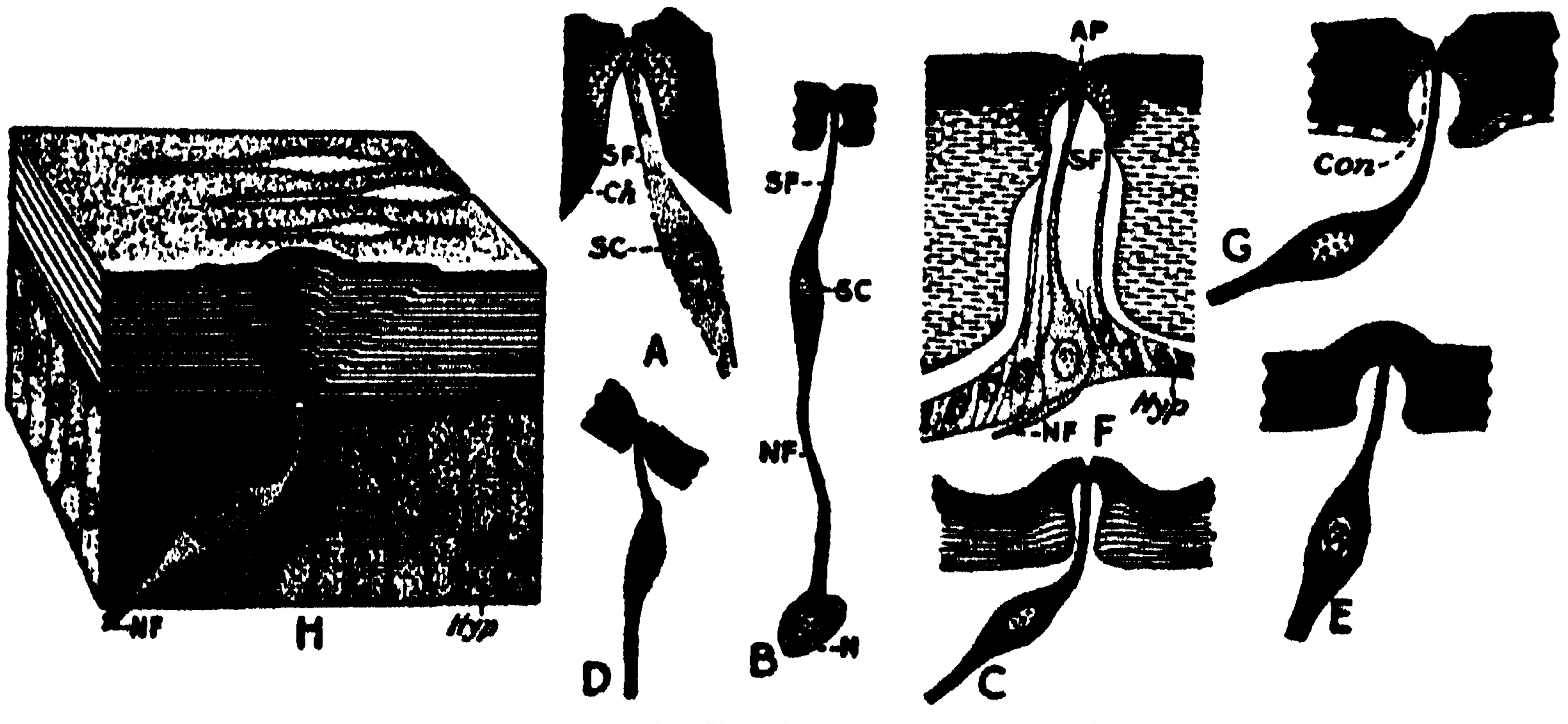


FIG. 3. OLFACTORY PORES

SHOWING INTERNAL STRUCTURE (A TO G) OF INSECTS AND LYRIFORM ORGANS OF SPIDERS (H). A, FROM LEG OF A HONEY-BEE; B, FROM ELYTRON OF A BEETLE; C, FROM A LEG OF A LADY-BEETLE; D, FROM SECOND ANTENNAL SEGMENT OF A GRASSHOPPER; E, FROM WING OF A SILKWORM MOTH; F, FROM ANTENNA OF A BEETLE LARVA; G, FROM MAXILLARY PALPUS OF A TOMATO WORM, AND H, A DIAGRAM REPRESENTING A BLOCK FROM LEG OF A SPIDER, SHOWING SURFACE VIEW OF THREE LYRIFORM ORGANS AND ONE IN SECTION. THE CHITIN (*Ch*) OR CUTICULA IS SHOWN BY SOLID BLACK IN ALL THE FIGURES, EXCEPT C, F AND H; IN C AND F ITS TWO LAYERS ARE REPRESENTED. *AP*, PORE APERTURE; *Con*, CHITINOUS CONE; *Hyp*, HYPODERMIS; *N*, NERVE FIBER; *SC*, SENSE CELL, AND *SF*, SENSE FIBER.

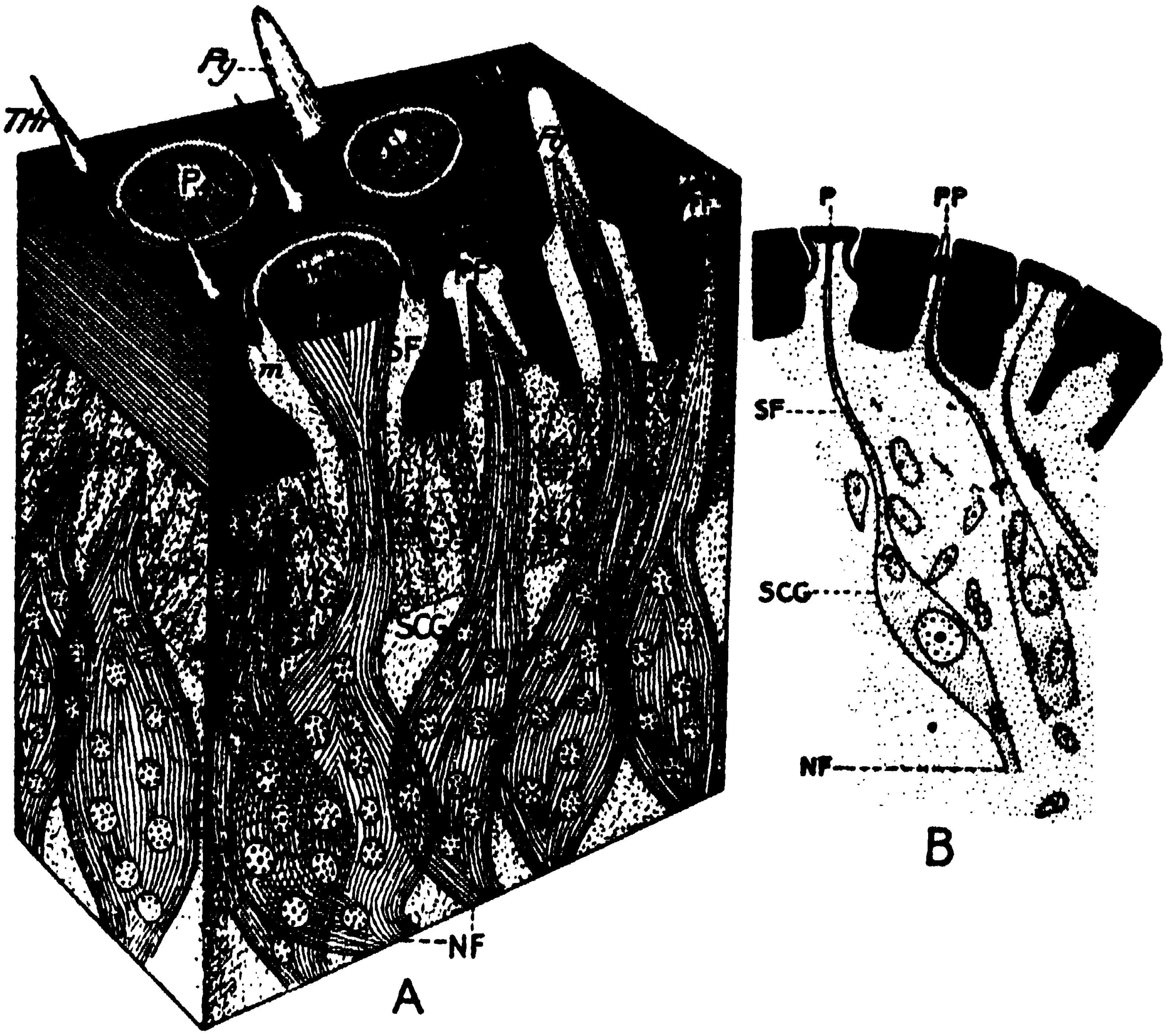


FIG. 4. EXTERNAL AND INTERNAL STRUCTURE OF ANTENNAL SENSE ORGANS MOST OF WHICH ARE CONSIDERED SMELLING ORGANS. A, DIAGRAM REPRESENTING A BLOCK FROM TIP END OF ANTENNA OF A WORKER HONEY-BEE, SHOWING TOUCH HAIRS (*THr*), PEGS (*Pg*), PIT PEGS (*PP*), FOREL FLASKS (*FF*), AND PORE PLATES (*P*) IN BOTH PERSPECTIVE AND SECTION. *Note.*—THE MANNER IN WHICH THE SENSE FIBERS (*SF*) JOIN THE PLATES AND HAIRS IS DIFFERENT FROM THAT FIGURED BY MORE RECENT OBSERVERS, BUT IN EVERY CASE THE FIBER IS SEPARATED FROM THE OUTSIDE AIR BY A LAYER OF CUTICULA. B, LONGITUDINAL SECTION THROUGH AN ANTENNA OF A WATER-BEETLE, SHOWING TWO PORE PLATES (*P*), A PIT PEG (*PP*), SENSE CELL GROUP (*SCG*), NERVE FIBER (*NF*), AND SENSE FIBER (*SF*). (AFTER HOCHREUTHER.)

tain cultures, and chemists are constantly using their olfactory organs as a help in analysis.

As we all know, industries of vast importance have been based on the knowledge of the senses gained through scientific investigation, and these industries, in many cases, have grown to such proportions that they have dwarfed, in the public mind, the sciences that gave them birth. As examples might be mentioned the telephone industry, based on the sense of hearing and the science of acoustics, and the moving-picture industry, based on the sense of sight and the science of optics. The perfume industry, also, based on the sense of smell, has grown to such proportions that the perfumers have included the subject of smell as a part of their business, forgetting that their industry belongs to smell and not the reverse! "How's that?" they may say. "Perfumes are made to be smelled," we reply, "and had man been created without a smeller there would have been no perfume industry, involving millions of dollars and employing thousands of people, ranging all the way from day laborers to the most highly trained organic chemists." Besides stimulating researches in chemistry, botany, zoology, physics, and even anthropology, the perfume industry has opened up a special line of agriculture devoted to the growing of many plants which would not otherwise have been produced. It should be stated also that in the endeavor to produce highly perfumed flowers many of our cultivated plants highly prized for their color have resulted. The subject of perfumery in all its phases is so large that volumes have been written on it, and its history, including that of cosmetics and soaps, which accompany perfumes, reaches into the remote past. How many users of perfumes and cosmetics to-day are aware that they are still slightly in debt for their personal attractiveness to the efforts of early civilized man, particularly the early Egyptians? This part of the story reads like a romance but can only be mentioned here.

ACUTENESS OF SMELL IN MAN

Literature contains a number of references to the remarkable acuteness of the sense of smell in the aborigines of various countries. The smelling power of these primitive peoples is inconceivable to the average civilized person, and consequently the reader may believe or disbelieve these reports as he likes.

Ethiopians and North-American Indians have a remarkably keen sense of smell, which in part accounts for their wonderful power of trailing their enemies. An old history of the Antilles assures us that some of the Negroes there can, by smell alone, distinguish the footsteps of a Frenchman from those of one of their own race. We are told that the cannibals and snake-eating tribes of Queensland by smell alone hunt and find a large species of boa upon which they live. Lumholz, the observer in this case, with his nose to the ground, could not distinguish the odor which these tribesmen were following with ease. Darwin cites the observations of Humboldt, who reported that certain Peruvian Indians could follow a trail by scent as reliably as a hound. Another writer asserts that he repeatedly conducted experiments which proved that Negroes and Indians recognize persons in darkness by their odors.

In civilized man the sense of smell is most highly developed in the blind. A boy, James Mitchell, was born blind, deaf and dumb, and depended chiefly on smell for keeping himself in touch with the outer world. He readily observed the presence of a stranger in the room and formed his opinions of persons apparently from their characteristic smells.

One writer claims that every individual has his or her own odor, as distinct and personal as is his countenance. As is well known, a dog can easily distinguish these odors, and by them can tell one person from another. We constantly exude products of metabolism through the skin and, since these products always differ, no two of us are alike in regard to odors emitted. Another writer remarks that a person is generally unable to appreciate the differences in odor of the secretions of the skin under different strong emotions, although there is abundant evidence that the nature of these secretions is modified by emotions. What a different world we should live in if the nose could analyze the various emotions so that we could easily distinguish sincerity and sanctity from deceit and villainy! A third writer has devoted a whole chapter to "smell and the personality," and believes that a person's odor has much to do with his personality. He says he is acquainted with English people who are able to recognize by smell not only different races and two sexes, but even different persons. One of these supersensitive acquaintances states that to her the odorous atmosphere of a person is every whit as characteristic and unmistakable as is the play of features or the carriage of the figure. A fourth writer remarks that the African native has a disagreeable smell to the nostrils of the European,

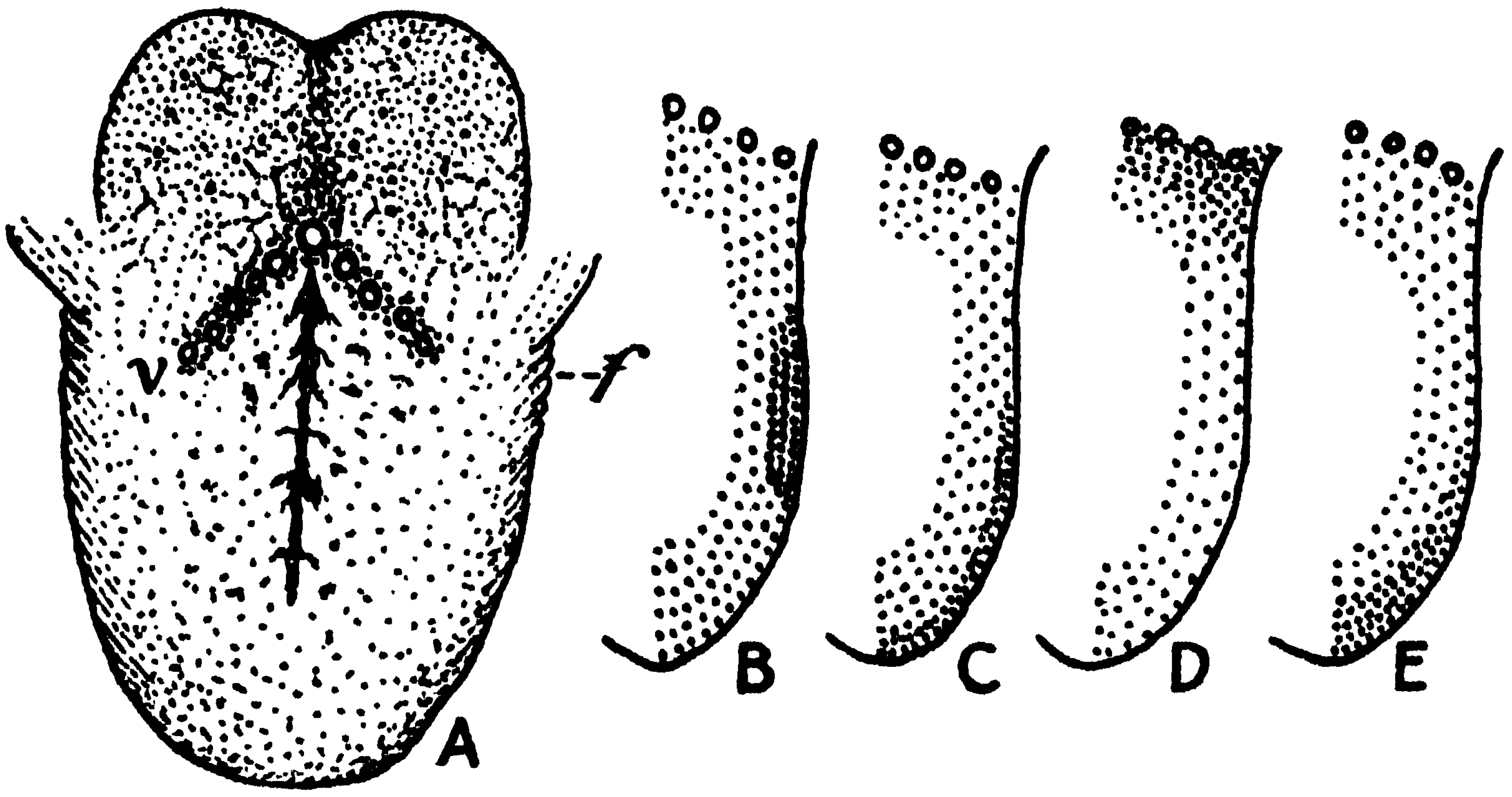


FIG. 5. THE LOCATION OF PAPILLÆ AND TASTE ORGANS ON THE HUMAN TONGUE

A, DORSAL VIEW OF TONGUE, SHOWING FOLIATE PAPILLÆ (*f*) AND VALLATE PAPILLÆ (*v*); B, THE SOUR TASTE, CONCENTRATED ON THE EDGE; C, THE SALTY TASTE, CONCENTRATED AT THE TIP AND ON THE EDGE; D, THE BITTER TASTE, CONCENTRATED AT THE BASE, AND E, THE SWEET TASTE, CONCENTRATED AT THE TIP. (ALL FROM PARKER; B TO E, MODIFIED AFTER HÄNIG.)

and that the European is still more offensive to the olfactory sense of a Japanese.

Since no two individuals emit identical body odors, and since the sexes differ in certain respects in their anatomy and physiology, we can imagine that they also differ in odor. Some human beings who have the power to distinguish individuals by smell have described the personal odor as usually agreeable; and often in the case of the opposite sex, as exciting passion. The odors of butterflies and moths play a great part in the courtship of these insects, thereby stimulating the mating instinct. We react, says one writer, to scents in somewhat the same way, and usually for the same reason, although unconsciously. He further claims that sweet scents arouse the mating instinct, and since perfumes are used largely by women, he believes that these have the same effect. His final conclusion is that a sweet scent is one which will stir the instinct of courtship without evoking the idea of its natural end and object.

Smell and sex have been correlated since ancient times, but the subject of smell was long ago tabooed, chiefly on account of this correlation. This may explain why our knowledge of the subject has not progressed further, notwithstanding that much has been written about it by various classes of authors. As substantial evidence of the part played by smell in matters of sex, we are referred to the lower animals, particularly to dogs, and then taken back to the time of Aristotle as a starting point for the remainder of the story. Further than that, it is known that erectile tissues have been found in the human nose, and the correlation between this structure and the generative organs has long been a matter of universal medical knowledge.

Several writers claim that woman, in all ages, has appealed largely in courtship to the olfactory sense of man. Through all the ages there has been a definite relation between the nose and sex, although the human species has been practically unconscious of it. This subject should be thought of as beautifully expressed by Tennyson:

> Through all the centuries the season of flowers—the springtime—has been celebrated in amatory song and story as the season of love and of sexual delight.

Our sense of smell in relation to certain aromatic chemicals appears to be astonishingly acute, judging from the results obtained by Fischer and Penzoldt in experiments with chlorphenol and mercaptan. Assuming that 50 cubic centimeters of the scented air in the room in which these chemicals were evaporated were sufficient for olfaction, the quantity of chlorphenol smelled in this test was only 1/4,600,000 of a milligram, and the quantity of mercaptan was only 1/460,000,000 of a milligram. This infinitesimal quantity of mercaptan, however, was estimated to contain 200,000,000,000 molecules. Of all the aromatics tested by various investigators, artificial musk has been found the most stimulating and it thus stands at the head of all olfactory stimuli. The most active mercaptan (propyl mercaptan) tested by Allison and Katz was perceived at a concentration of 0.006 milligram per liter of air, which is equal to 6/1,000,000 of a milligram per cubic centimeter. This figure is far removed from that of 1/23,000,000,000 of a milligram per cubic centimeter, furnished by Fischer and Penzoldt.

In spite of the numerous discrepancies between the results of various investigators, we must admit that olfaction is accomplished through very small, often infinitesimal, quantities of substances; and yet these quantities involve large numbers of molecules of the aromatics.

The reader may wonder how such large discrepancies come about. Briefly stated, because smell is not yet a true science; that is, we have no means of measuring odors, except by our noses, and no two noses have the same smelling ability. Further than that, the procedure of preparing and using odorous materials is not standardized. With these handicaps, it is hardly possible for the investigators to obtain similar results.

Smell and Taste do not differ Widely

Smell and taste in man and the higher animals are closely related, and often can not be separated, and in the lower animals they can scarcely be separated at all. In the higher animals the organs of both are stimulated by substances in solution. Materials to be tasted are mixed with or dissolved by saliva in the mouth, while odorous particles are dissolved by the mucous covering of the olfactory organs in the nose. Parker and Stabler say:

> We therefore definitely abandon the idea that taste and smell differ on the basis of the physical condition of the stimulus, a state of solution for taste, a gaseous or vaporous condition

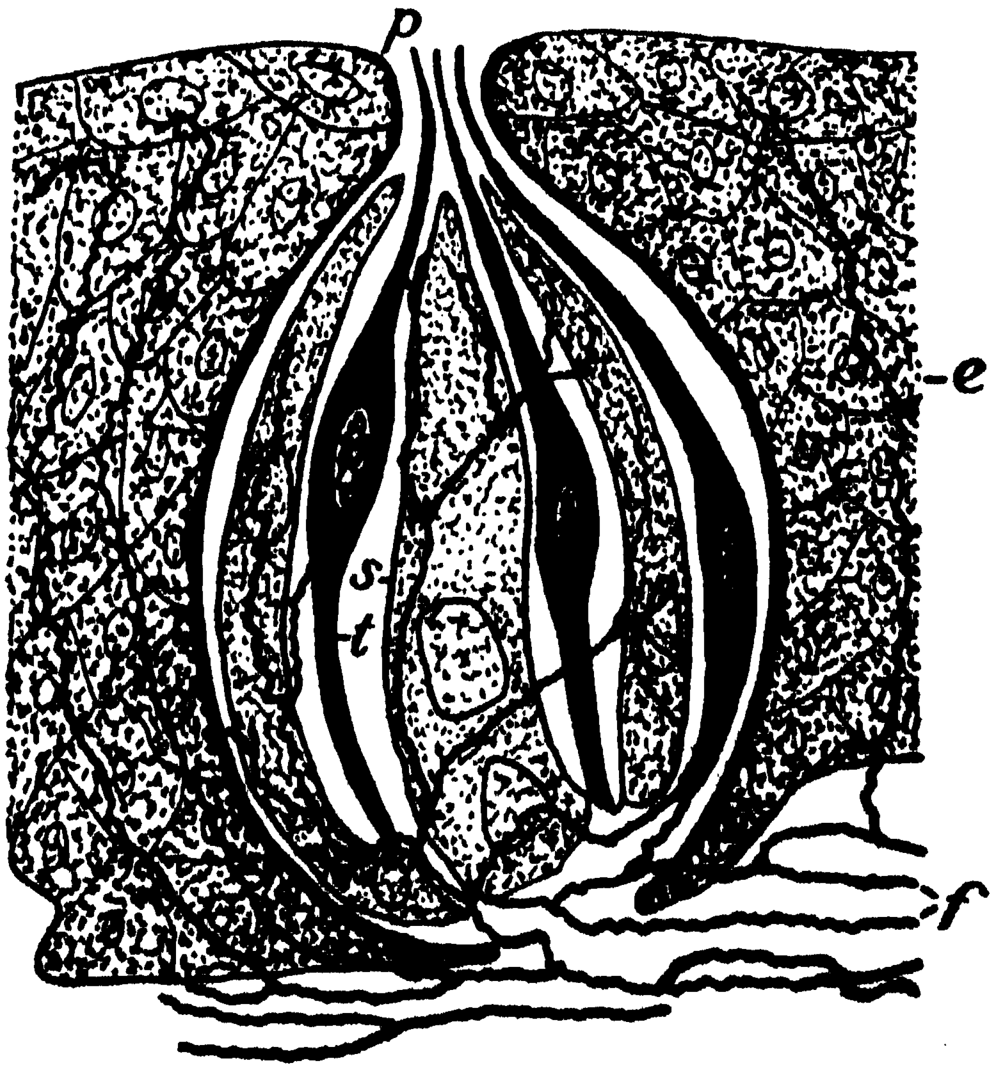


FIG. 6. A SINGLE TASTE-BUD FROM THE HUMAN TONGUE

SHOWING THE NERVE FIBERS (*f*) INDIRECTLY INNERVATING THE SURROUNDING EPITHELIUM (*e*), THE SUPPORTING CELLS (*s*) AND TASTE CELLS (*t*), WHOSE OUTER ENDS PROJECT INTO AND SOMETIMES BEYOND THE PORE (*p*). (FROM HERRICK, AFTER MARKEL-HENLE.)

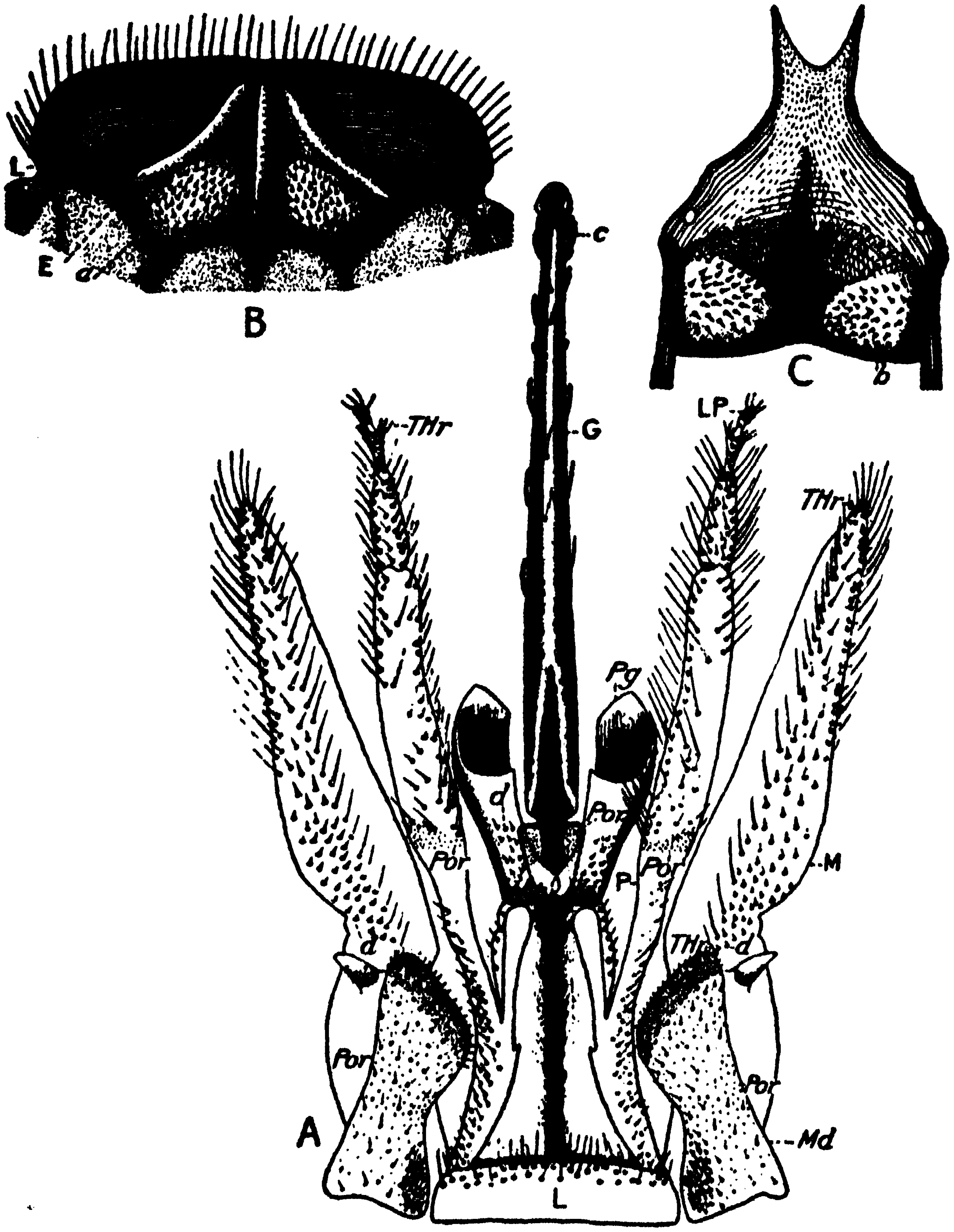


FIG. 7. THE MOUTH PARTS OF HONEY-BEE

SPREAD OUT FLAT, SHOWING LOCATION OF SO-CALLED TASTE ORGANS (*a* TO *d*), OTHER TOUCH HAIRS (*THr*) AND OLFACTORY PORES (*Por*). A, DORSAL SURFACES OF TONGUE OR GLOSSA (*G*), PARAGLOSSA (*Pg*), PALPIGERS (*P*) AND LABRUM (*L*), INNER SURFACES OF LABIAL PALPI (*LP*) AND OUTER SURFACES OF MAXILLÆ (*M*) AND MANDIBLES (*Md*); B, VENTRAL VIEW OF EPIPHARYNX (*E*) AND LABRUM (*L*), AND C, INNER SURFACE OF PHARYNGEAL PLATE. ALL THE HAIRS SHOWN ARE INNERVATED, WHILE THE EXTREMELY LARGE ONES ON THE TONGUE HAVE BEEN OMITTED.

for smell, and maintain that both senses are stimulated by solutions, though in smell, at least for air-inhabiting vertebrates, the solvent is of a very special kind. . . . In air-inhabiting vertebrates, the olfactory solvent is a slimy fluid of organic origin and not easily imitated. . . . We therefore believe that we are correct in concluding that we smell enormously attenuated solutions and taste only relatively strong ones. In this respect the two senses may be said to differ from each other more or less as ordinary scales do from a chemical balance; taste is used in determining the presence of relatively large amounts of substance, smell for only the most minute quantities.

From all that has been written on the theory of odors we may conclude that smell depends (1) upon the volatility of the odorous substance, (2) on the solubility of the odorous particles in the watery mucus of the nose, (3) on their solubility in the fatty or lipoid ends of the olfactory cells, and (4) on the chemical reaction which takes place in these cells. A substance, says Durrans, which fails to satisfy any one or more of these factors is odorless, and it is obvious that variations in these factors will produce variations in both the intensity and quality of odors. Durrans believes that the quality of odor is determined primarily by the chemical properties of a substance, whereas the intensity is simultaneously governed by the physical properties.

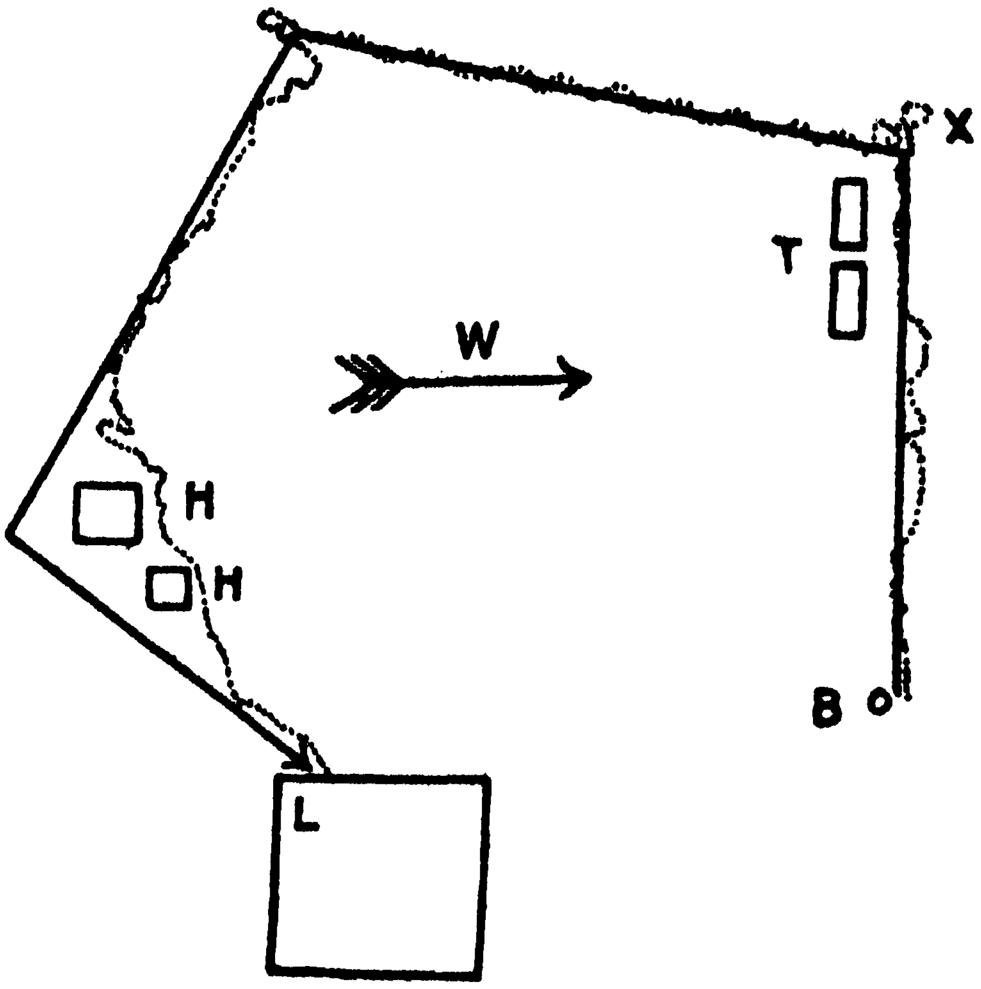


FIG. 8

On a level sandy place in Amsterdam a boy followed the route indicated by the solid line. This route departed from a tree (*B*) and ended at a laboratory (*L*). At *T* there were two street cars and at *H* two huts used by construction workers. Upon completion of trip by boy, a police dog was led to the tree where he was allowed to smell the boy's cap, and then followed the boy's trail as indicated by the dotted line. A strong wind was blowing in the direction indicated by arrow (*W*). Between tree and street cars the wind seems to have scattered scented sand, because the dog followed to the right of the boy's track, whereas behind street cars, trail was followed exactly. Where the boy turned to left at *X* the dog had some difficulty, as shown by his windings. Just before reaching the huts, the dog lost the trail, which is to be explained by the fact that many people were walking about, but he soon found it again and continued following it to the laboratory. (After Buytendijk.)

Much has been written, also, on the theory of taste, and nearly all the writers are agreed that taste is purely a chemical process, and not physical, as many claim for smell. Briefly stated, ions are usually the keys employed for unlocking the sensations of taste.

It is well known that flavors are smell sensations. To have a sensation of smell, an actual stream of air through the upper portion of the nose is necessary, and this is accomplished best by sniffing. That is, smell is accomplished by inspiration or breathing in through the nose, while the sensation of flavor is produced by expiration or breathing out through the nose, and the intensity of flavors is increased by smacking the lips, thus helping to force the scented air through the nose.

In regard to future research along the olfactory line, Hendrick says:

> The organic chemists have outstepped the physiologists; they have discovered molecular cousinships among certain odoriferous substances . . . we are engaged in what the commercial traveler calls a different line; what we want is the philosophy of smelling.
>
> In another respect research has been in progress for some time and there seems to be light in the offing. The entomologists are at work and they recognize this function in their study of insects.
>
> We are sorely in need of research along the olfactory line. We are still questioning as to the nature of electricity and what it is, but good men are working over it. With the phenomena of smell we are still medieval. . . . If we maintain a simple curiosity such as animates children and great men, there will come

> from laboratories one fact after another which has not been known before.

In other respects smell and taste do not differ widely. Both senses can be cultivated, fatigued and destroyed. Tastes have definite names while smells have indefinite ones. The location of their respective sense organs is definitely known in the vertebrates, but indefinitely known in the invertebrates. In structure these organs do not differ as widely as is generally believed. The olfactory organs in vertebrates are illustrated in figures 1 and 2, and in invertebrates in figures 3 and 4. Figures 5 and 6 represent taste organs in vertebrates, while figure 7 represents them in an invertebrate.

INSECTS CAN SMELL EQUALLY AS WELL AS THE HIGHER ANIMALS

For ages the dog's nose has been regarded as the most acute smelling organ possessed by any animal, but a review of the literature shows that the "noses" of insects are close competitors and possibly second to none. The sense of smell of the horse, cow, pig and elephant, and of many other domesticated and wild animals, is remarkably developed, and perhaps would compare favorably with that of the dog.

To show how well insects can smell as compared to dogs, Fabre tells us about hunting truffles, which are a species of mushroom growing under the ground.

> The dog finds the truffles by smelling the earth quite close to the tuber; but he finds his master at great distances by following his footsteps, which he recognizes by their scent. Yet can he find the truffle at a hundred yards, or his master, in the complete absence of a trail? No. With all his fineness of scent, the dog is incapable of such feats as are realized by the moth, which is embarrassed neither by distance nor the absence of a trail.

A Dutch writer makes the remarkable

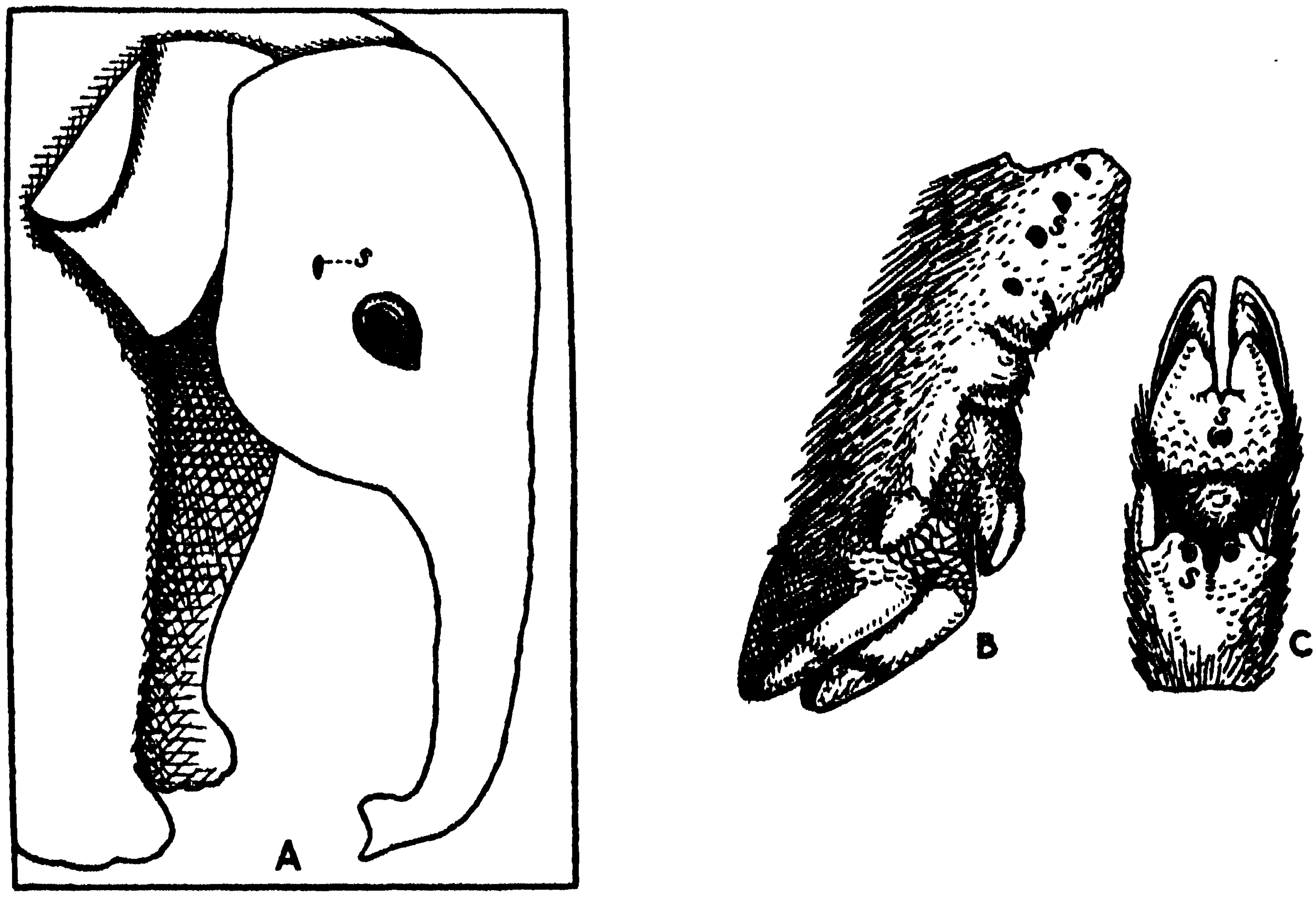


FIG. 9. THE LOCATION OF SPECIAL SCENT GLANDS IN ELEPHANT AND HOGS A, DRAWING FROM POCOCK'S PHOTOGRAPH OF A YOUNG MALAYAN ELEPHANT, SHOWING LOCATION OF TEMPORAL SCENT GLAND (*s*) BETWEEN EYE AND EAR; B AND C, UNDERSIDE OF FEET OF HOGS, SHOWING LOCATION OF SCENT GLANDS (*s*) ON FRONT FOOT OF COMMON PIG (B) AND ON HIND FOOT OF SOUTH AFRICAN BUSH-PIG (C). (AFTER POCOCK.)

statement that more than one person has been known to be able to smell sugar in tea and salt in soup; but that Albert, a police dog, smelled common table salt and quinine in solution at a concentration of 1 to 10,000. Albert was also able to associate a pocket-book with its owner, and to distinguish pebbles which had been touched lightly with the fingers.

The dog, like people, can experience a variety of olfactory qualities; furthermore, he has the power to analyze a mixture of odors and to attend exclusively to one component of it. This is a power that we lack almost entirely. The dog, and perhaps many other animals, can analyze a complex of odors as a trained musician analyzes a chord.

Dogs can trail men and animals merely by smell, as illustrated in figure 8. Ants and termites can follow their own tracks by smell, but in these cases there are other factors to be considered, although smell is probably the most important one.

Dogs can find hidden food merely by smell; so can insects. Flower-loving insects recognize their food partly by smell, but as dogs do not care for flowers no comparison can be made on this point. Male insects find their mates partly by smell; so do dogs.

It is known that honeybees, ants, and termites communicate largely by smell; perhaps the same is true of dogs, although as to this we have no definite information. Frisch has gone so far as to call smell the "language" of honeybees, and a small book could be written on this subject alone.

Means of producing Odors for Recognition

Long ago it was stated that most animals emit odors peculiar not only to the individual, variety, race, and species, but also to the genus, family, order, and class, and that these odors are the chief means by which one animal recognizes other animals. Without the aid of the eyes the degenerate human nose is able to distinguish a horse from a cow, a goat from a roe, a dog from a cat, a martin from a fox, a crow from a pigeon, a parrot from a hen, a lizard from a snake, and even a carrion crow from a hooded crow.

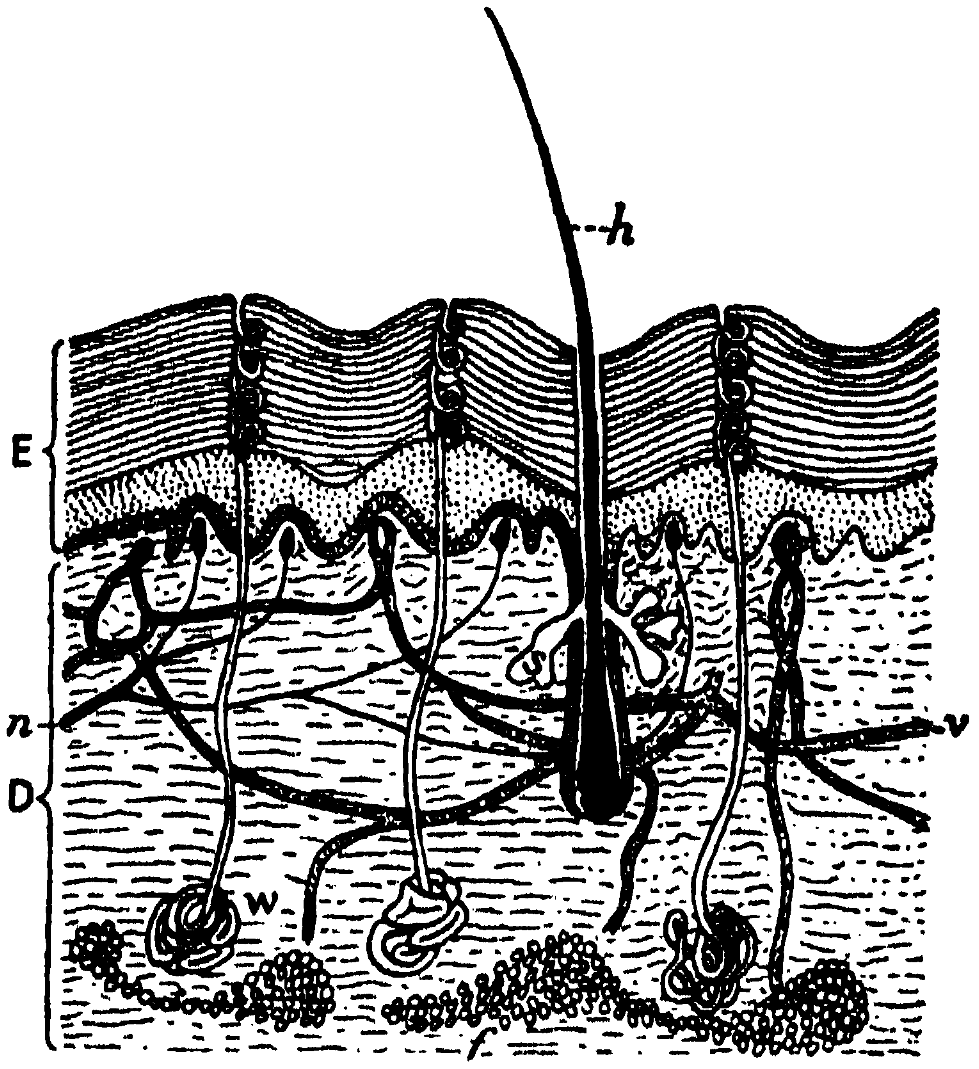


FIG. 10. SECTION OF SKIN OF MAN SHOWING EPIDERMIS (E); DERMIS (D); HAIR (h), ARISING FROM A HAIR FOLLICLE INTO WHICH EMPTIES SECRETION OF SEBACEOUS GLANDS (s); SWEAT GLANDS (w) AND THEIR DUCTS, WHICH PASS SPIRAL-LIKE THROUGH THE EPIDERMIS; BLOOD VESSELS (v); FAT CELLS (f), AND NERVE (n), WHICH INNERVATES THE SENSE PAPILLÆ. (FROM HERTWIG, AFTER WIEDERSHEIM, SLIGHTLY MODIFIED.)

All odors arising from the skin, hair, feathers, or scales of an animal have their sources in secretions or excretions which pass through the skin or integument by special ducts or pores, and not directly through by osmosis; in some animals, however, particularly certain insects, the existence of these pores has not yet been definitely established. The scent-producing organs, which may possibly include three types of glands—special scent glands, sweat glands and sebaceous glands—have not yet been thoroughly and systematically studied in any order of animals, and in most cases definite and specific functions have not been assigned to the various types. Odors may also be emitted from the body at either end of the alimentary canal, but these probably play no part in recognition among animals.

Special scent glands have been found in a large number of animals, including deer, antelope, goat, sheep, chamois, musk deer, musk ox, hog, elephant, bat, shrew, beaver, muskrat, and aard-vark. In the elephant (Fig. 9, A, *s*) the large gland lies beneath the skin of the face. It enlarges in the male at the rutting season, and the secretion has a strong musky odor. Our commercial musk comes from the bag of the musk deer, and our castoreum from the scent bag of the beaver. Both of these aromatics are used extensively in perfumes and medicines.

Since the anal glands have been found in such a wide range of mammals—from the lowest (duckbill) to the highest (man)—we may assume that they are common to a large percentage of mammals. Anal glands are also present in some insects. They are most constant and best developed, as a rule, in the carnivorous animals, where, in regard to the secretion produced, they reach their climax in the polecat of Europe and in the skunk of America, but the largest ones are found in the hyena.

Other special scent glands lie in the feet, and their secondary function is probably to leave scented tracks wherever the animal steps. Those in the feet of hogs (Fig. 9, B and C, *s*) are good examples.

The skin of mammals, in particular, is characterized by richness in glands, of which there are two kinds. Of these, sweat glands (Fig. 10, *w*) are common to mammals, while sebaceous or oil glands (*s*) are common to birds and mammals. The sebaceous glands usually open around the base of hairs (*h*) in depressions called hair follicles, and not into the cavity or lumen of the hairs. On the palms of a human being sweat glands number 1,100 to the square centi-

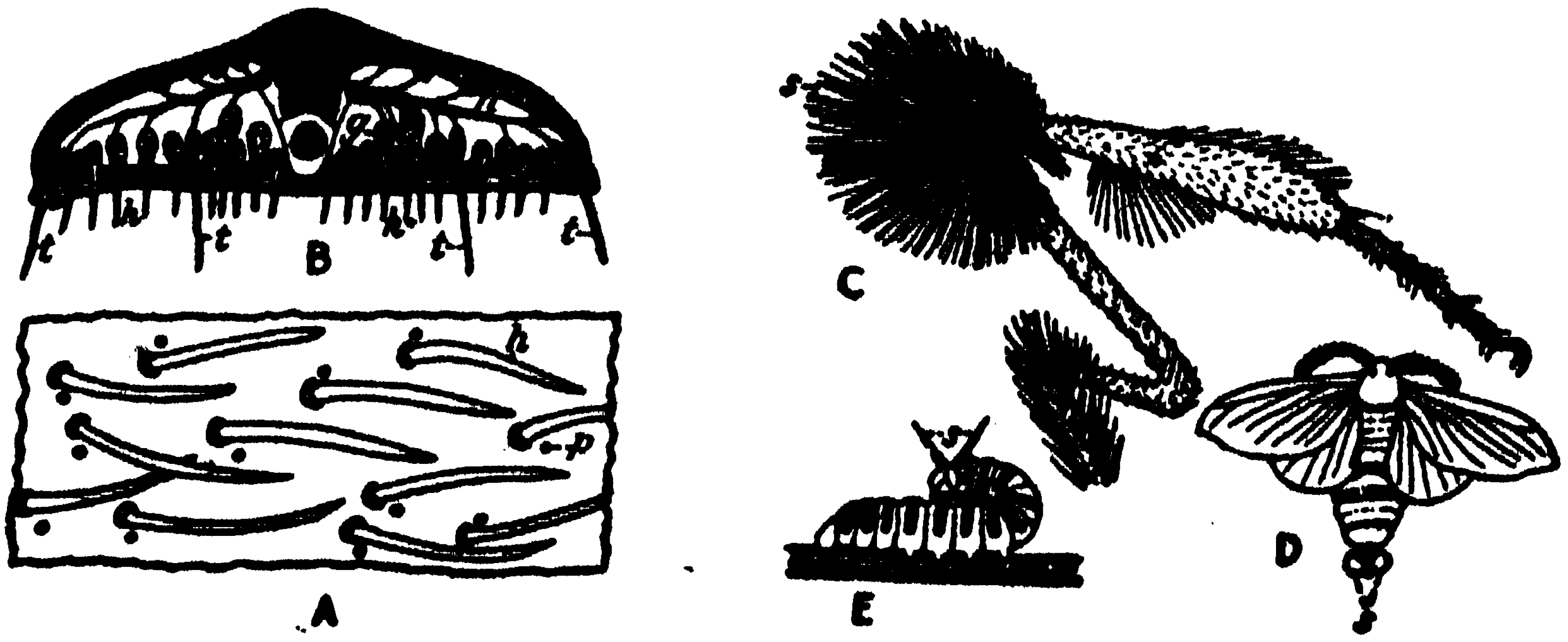


FIG. 11. THE LOCATION OF SCENT GLANDS OF INSECTS

A, superficial view from elytron of a cotton boll-weevil, showing large hairs (*h*) and widely scattered gland pores (*p*). B, cross-section through tarsus or foot of a beetle, showing nerves (*n*) running to touch hairs (*t*) and gland cells (*g*) which, when stimulated, force their sticky secretion through openings in numerous hairs (*h*) on the "soles" of the feet. (From Packard, after Dewitz.) C, front leg of a male moth, showing the fan-shaped group of scent hairs (*s*). (From Schröder, after Illig.) D, female of the silkworm moth, showing the eversible sacs (*s*) as scent-producing organs. (From Schröder, after Freiling.) E, larva of a swallow-tail butterfly, showing eversible sacs or osmaterium (*s*), which emit a defensive odor. (After Berlese.)

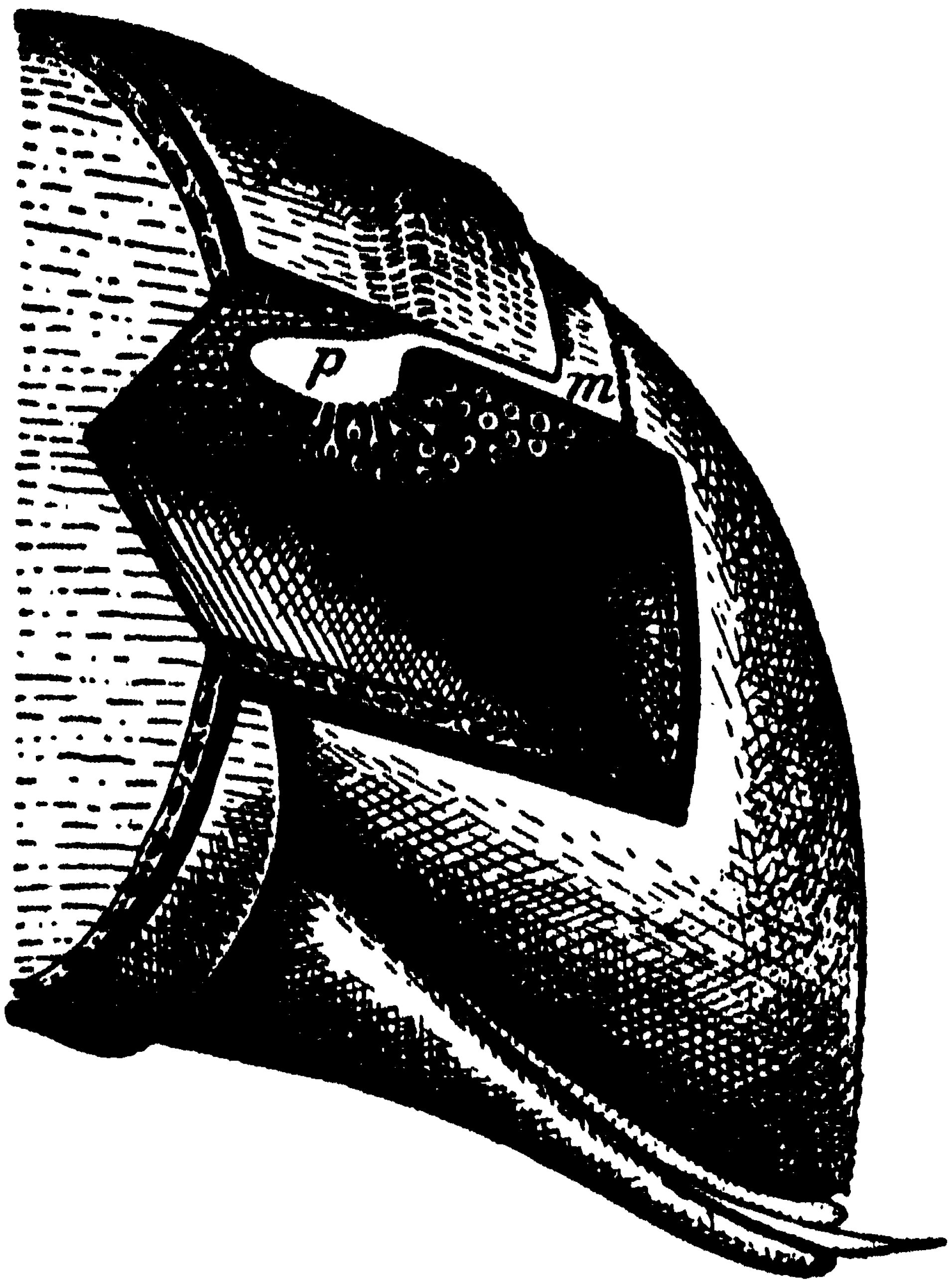


FIG. 12. THE END OF ABDOMEN OF A HONEY-BEE

DIAGRAMMATIC TRANSVERSE-LONGITUDINAL VIEW, SHOWING SCENT-PRODUCING ORGAN COMPOSED OF ARTICULAR MEMBRANE (*m*), CANAL OR POUCH (*p*), AND NUMEROUS GLAND CELLS LYING BENEATH THIS POUCH.

meter, and their total number in man is said to be about two million.

Horses and some other animals sweat freely, but it has been said that the dog, cat, rabbit, rat and mouse do not sweat at all, or, if they do, only between the toes. This statement expresses only part of the truth, because these animals do perspire on other parts of the body, although not to any perceptible extent except on their footpads.

Primarily the sweat glands constitute an automatic device for holding the body temperature at a constant degree, while their secondary function is probably recognition. The perspiration is a clear, colorless fluid with a salty taste and of different odors from different parts of the body. Sweat is 99 per cent. water and the other 1 per cent. consists of urea, ammonia, fatty substances and certain other compounds. Its neutral fats are said to come from the sebaceous glands, although the sweat glands themselves secrete other fatty substances, of which the volatile fatty acids emit the peculiar odor characteristic of sweat.

The primary function of the sebaceous glands is to lubricate the skin, hair and feathers of animals; if they have a secondary function it might be recognition. The secretion of these glands, called sebum, is an oily semifluid when fresh, but on the surface of the skin it solidifies, forming a greasy coating.

We can now understand why the odors emitted from two animals differ. We can also understand how dogs, by smell alone, even in total darkness, can distinguish their masters and the members of their households from strangers. Besides the glands already mentioned, animals have certain other glands whose secretions may also be odorous and perhaps sexually attractive; for instance, the glands connected with the genitals.

Sweat glands and sebaceous glands are present in the higher animals, but absent in insects; therefore insects, so far as we know, do not sweat. They belong to the cold-blooded animals, whose temperature most of the time corresponds more or less closely to the temperature of the air in which they live, and therefore do not need sweat glands. Nevertheless, many insects possess glands which, being widely distributed over the entire body surface, closely resemble sebaceous glands. Since these glands are not needed for lubricating purposes, they must have some other function, and that they are used for recognition seems very reasonable. Those of the cotton boll weevil (Fig. 11, A, *p*) illustrate this point.

As specialized glands under this type are the adhesive glands (Fig. 11, B) in the feet of many insects, particularly in

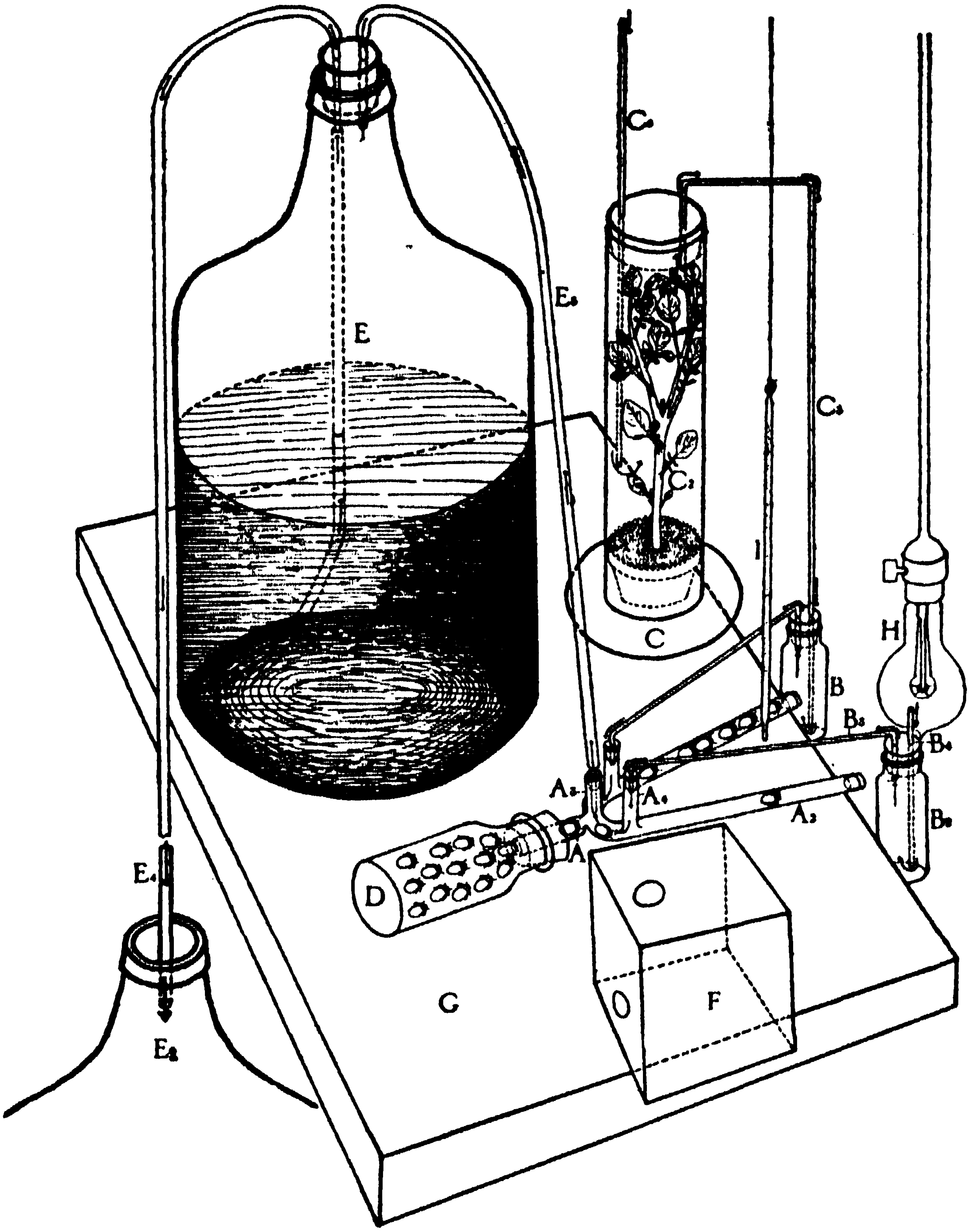


FIG. 13. AN INSECT OLFACTOMETER

SHOWING THE FOLLOWING PARTS; *A*, STEM OF Y-TUBE; A_2, FORKS OF Y-TUBE; A_3, EXIT OF Y-TUBE; A_4, ENTRANCE TUBES OF Y-TUBE; *B*, BOTTLE TO HOLL ODOROUS SUBSTANCE; B_2, BOTTLE TO HOLD CONTROL SUBSTANCE; B_3 AND B_4, EXIT AND ENTRANCE TUBES OF BOTTLES *B* AND B_2; *C*, PLANT CHAMBER; C_2, LIVING POTATO PLANT; C_3 AND C_4, EXIT AND ENTRANCE TUBES OF PLANT CHAMBER; *D*, DARK BOTTLE TO HOLD INSECTS; *E* AND E_2, FIVE-GALLON BOTTLES, THE LATTER STANDING ON THE FLOOR; E_3 AND E_4, SIPHONS, THE LATTER FOUR FEET LONG; *F*, FIVE-INCH CUBIC BOX, THROUGH WHICH Y-TUBE IS INSERTED, TO ELIMINATE SIDE LIGHTS, ETC.; *G*, THICK BOARD; *H*, ELECTRIC LIGHT; AND *I*, THERMOMETER.

all of those that can walk on perpendicular surfaces, or even upside down. Although the primary function of these glands is certainly to enable insects to walk on smooth perpendicular surfaces, a secondary use is probably that of recognition. In ants, termites, and all the other insects which follow scented trails this secondary use seems especially plausible. The adhesive glands lie in the soft pads on the under side of the feet, and are usually connected with small hairs, called tenent hairs (*h*). These hairs are hollow, and usually open at their tip ends; and through them the sticky secretion from the glands is forced to the exterior, where under certain conditions it may be seen as fine threads. This example shows how scented trails may possibly be made by the feet of insects in much the same way as scented tracks are made by dogs, the sweat glands in the pads of the dogs' feet seeming to deposit an odorous material wherever a dog steps. Further than this, ants and termites have been observed to lay down scented trails by depositing tiny specks of material from the tip ends of their abdomens, and thereafter they follow these tracks.

Scent glands of a second type include peculiarly arranged tufts of long hairs on the legs and elsewhere on male moths (Fig. 11, C, *s*). The secretions from all these organs have been credited with purposes of allurement and are supposed to attract the opposite sex. They have been regarded as aromatic, volatile oils. Their odors usually are, to man, very pleasant indeed, and have been described as resembling many of our most pleasing scents, even including those from some of our fancy perfumes. As a rule each species of insect has its own characteristic odor.

In the case of a third type of scent glands, eversible sacs or pouches, usually lined with tiny hairs which connect with the glands, serve as special devices for storing the secretion and distributing the odors. With some species the odors from these glands serve for allurement (Fig. 11, D, *s*), and in the case of other species for defense (Fig. 11, E, *s*).

The dorsal scent gland of the honeybee (Fig. 12) belongs to a fourth type, and is one of the most highly developed of the scent glands used for recognition purposes.

The anal glands of insects, already

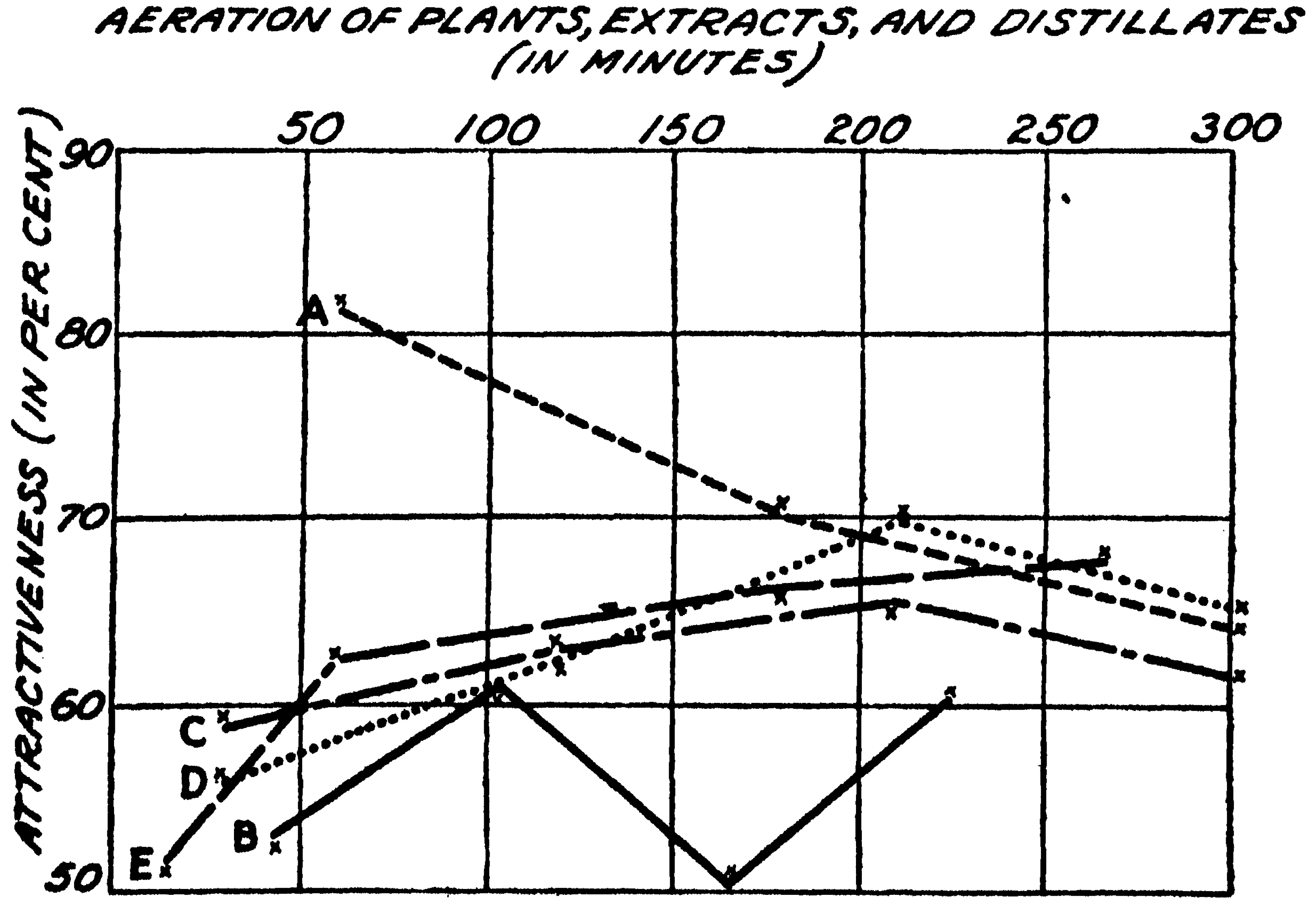


FIG. 14. THE RESPONSES OF POTATO BEETLES

TO EMANATIONS FROM THEIR LIVING HOST PLANTS, AND TO ODORS FROM WATER EXTRACTS AND STEAM DISTILLATES OF THESE PLANTS. *A*, SMALL POTATO PLANT, POTTED NINETEEN DAYS; *B*, SMALL BRANCH OF TOMATO PLANT IN WATER; *C*, EXTRACT OF POTATO FOLIAGE; *D*, EXTRACT OF JIMSONWEED; AND *E*, DISTILLATE OF POTATO FOLIAGE. THE FIRST POINT IN EACH CURVE REPRESENTS A SINGLE RESPONSE, WHILE EACH OF THE OTHERS REPRESENTS THE AVERAGE OF FOUR INDIVIDUAL RESPONSES.

mentioned, belong to a fifth type, and are supposed to serve only as defensive weapons.

USES OF SMELL AND TASTE IN ECONOMIC ENTOMOLOGY

The perfume industry is perhaps the most important practical application of smell, and the writer ventures to say that in economic entomology is found its second most important one. Few people realize the part which smell and taste play in helping to control insects. The information gained while using attractive baits and repellents to control insects has come about in a haphazard way, by the trial-and-error method, the most laborious and expensive procedure of all. We should no longer be compelled to use this method, but since no definite rules have been established there seems to be no other way of attacking problems dealing with the senses depending upon chemical properties. The likes and dislikes of insects in regard to attractive and repellent odors are so different from our own that a person's sensations can not be used as a guide. This paper is meant chiefly as a plea for more and better fundamental research on smell and taste, so that the information obtained may be applied more advantageously.

1. USES OF SMELL IN BEEKEEPING

Smell seems to be the chief factor on which the social life of a colony of bees is founded, and it is the sense utilized by the beekeeper in controlling them. The use of smoke has been found the most available means of controlling bees, but it might be argued that smoke is an irritant and does not necessarily control bees by affecting their smelling organs. This question is debatable, although bees can detect smaller quantities of smoke than can a person, and a small amount of it does not irritate us.

Other facts relating to smell in beekeeping are as follows: (1) A new hive odor is formed in uniting colonies. (2) The foreign hive odor is eliminated when queens are introduced. (3) Bee odors help in catching swarms. (4) The absence or presence of the queen odor helps us to tell whether or not a colony is queenless, and aids us in locating lost queens.

2. ATTRACTIVE BAITS HELP TO CONTROL MANY INSECTS

It is questionable whether smell is the only sense used by insects to distinguish attractive baits; taste should therefore be included, although the writer believes that insects lack a true sense of taste. Two kinds of odorous materials are used in controlling insects, attrahents, usually called "attractants," and repellents.

The more extensively science is applied to better living, the more man thinks of ridding himself of his numerous pests. For ages grasshopper or locust plagues were tolerated as if an efficient control were impossible, and, in fact, there would still be no preventive had not economic entomologists prepared a food which proved more attractive to grasshoppers than are their natural food plants.

Attractive poisoned baits for grasshoppers were first tried in 1885 in California. They consisted of bran, arsenic, sugar and water. Cheap molasses was later substituted for the sugar, and even to-day molasses is still generally used, although some writers doubt whether it really adds to the attractiveness of the bait. By 1892 grasshopper baits, consisting of bran, Paris green, molasses and water, were found successful. After entomologists had prepared a food which grasshoppers liked better than their natural one, the next problem was to improve it in every way possible, particularly in regard to its inexpensiveness and attractiveness. Finely chopped oranges or lemons were added to make the bait more attractive. Many other substances have since been tried as attractants, but the next important step was the substitution of amyl acetate or banana oil for the very much more expensive oranges or lemons in the bait. Now let us cite one example of recent grasshopper campaigns to show the immense quantities of poisoned bait used and the millions of dollars saved by its application.

In 1921 war was declared against grasshoppers in western Canada, and the campaign was organized on a semimilitary basis. In Saskatchewan the supplies furnished to the municipality amounted to 2,720 tons of bran, 225 tons of sawdust, 112,636 gallons of molasses, 2,805 cases of lemons, 166 tons of arsenic, 34 tons of Paris green, and one barrel of amyl acetate. The campaign in this province alone is estimated to have saved the crops on 1,400,000 acres.

Attractive poisoned-bran baits are also used as control measures against armyworms, cutworms, crickets, and earwigs, thus saving the farmers and others millions of dollars.

Everyone knows that ants are very fond of sweet foods. At first thought, therefore, it would seem an easy matter to induce ants to eat poisoned foods; not so, however, for they are too "smart" to be easily fooled in such a manner. In fact, man with all his intelligence had to experiment a long time before he succeeded in preparing a poisoned food which they relished and would carry to their young in the nest. Perhaps Solomon with all his wisdom could not have succeeded in this difficult task.

Ants have always been found very difficult to control even when all known measures have been employed against them. Poisoned baits for ants were formerly not considered successful and were seldom recommended. The first poisoned baits tried against ants were very simple, consisting of a sweet substance, sugar sirup or honey, to which was added poison such as arsenic or Paris green. From time to time other substances were added to the sweet liquids, but very little improvement resulted in this way. The greatest improvement was the discovery of the proper proportion of the ingredients, and the best method of combining them. But this discovery was not made by our economic entomologists until about 1909, when the presence and spread in our southern states of the Argentine ant, the worst ant pest the world has ever known, demanded a far better material and method for ant eradication than any that had been devised. After many trials and failures, or partial failures, a satisfactory bait was finally prepared which is now generally recommended as a remedy against all noxious ants. It contains honey, sugar, water, sodium arsenite, tartaric acid and benzoate of soda. Great care has to be exercised in preparing this bait, and particular attention has to be paid to the cleanliness of the vessels used, for if the bait accidentally becomes flavored with any undesirable substance the ants will "leave it severely alone."

In 1922 the Argentine ant was discovered in Mississippi, and since then successful campaigns have been waged against it by the use of thousands of cans of the bait described above. The State reports for 1926 declared that the ant campaigns had been entirely successful and that complete eradication in Mississippi seemed near at hand; they remarked that the people knew that if this ant was not eradicated, every property and every house, barn, store, and other building would become infested, thus causing an annual loss of millions of dollars not only to themselves, but later to their children and grandchildren. War against this ant by the poisoned bait method is also being successfully waged in our citrus orchards, especially those of California, and in foreign countries.

The struggle against the olive fly,' the worst enemy of the olive tree, has been a long and hard contest that has seriously taxed the ingenuity of man, and apparently no progress was made until some one discovered that the olive fly had a "sweet tooth," and could be led to its doom by attraction to poisoned sweet foods. How this was finally accomplished is a long story, extending over a quarter century, and can not be related here. It appears, however, that all the countries troubled with this pest are now generally using the method, which consists of spraying with a poisoned sweet, and that they spray only a part of each olive tree; in fact, only enough of it to attract the olive fly. This reduces the danger to beneficial insects, which are more abundantly attracted when the entire tree is sprayed. A syndicate for controlling the olive fly has been organized in Italy and a standard formula—90 gallons of water, 100 pounds of molasses, and 2.5 or 3 pounds of sodium arsenite adopted for the spray. Thus the seemingly trivial discovery that olive flies are attracted by sweet substances has led to practical methods whereby the olive industry in many parts of the world, involving millions of dollars, has been saved.

Other fruit flies, including the Mediterranean fruit fly and the melon fly, are partly controlled by attractive baits. The house fly and its near relatives are attracted by many substances used as baits, but we are not yet certain what constituent or constituents in their food really do the attracting. More research is badly needed here.

Many efforts have been made to discover successful attractants for noxious moths and beetles, but so far few practical methods have been devised, although work along this line is now being carried on more seriously than ever before, and the results already obtained are very promising. This work has dealt chiefly with the codling moth, which causes wormy apples, the oriental peach moth, and the Japanese beetle. The most promising and striking example of how a definite chemical constituent can allure myriads of insects to their destruction is the use of baits scented with geraniol to attract Japanese beetles, as recently demonstrated by Richmond, at Riverton, N. J. For twenty years or more much has been done toward developing a remedy for the strawberry root weevil, but not until recently has a satisfactory control measure been discovered. An attractive poisonous bait has at last been developed by Forsell. It is claimed that the discovery and perfection of this bait marks an important horticultural step in the fruit industry of the state of Washington, because this weevil had become so serious in many places that the strawberry-growing industry seemed doomed.

3. Repellents help to control Many Insects

As already stated, attractants lure insects to traps or to poisoned baits where they may be killed by sprays or otherwise, or where they die after eating the poisoned food. Most repellents, on the other hand, are usually effective for short periods only and have to be frequently renewed. For a time they will keep harmful insects a short distance from our bodies and those of our animal friends or from our cultivated plants. A few repellents, nevertheless, may be effective under certain conditions for long periods. As examples, those employed to repel insects from stored clothing and museum collections of insects and other animals may be cited.

Smoke has been referred to as a repellent to control honeybees, and it is also an effective one against mosquitoes and biting-flies.

Many substances used as repellents emit poisonous exhalations. It is questionable whether in these cases it is primarily through the action of the olfactory sense that the insects are driven away. In other words, we do not know whether the repellent effect is caused by the stimulation of the smelling organs by these exhalations or whether the insects are injured by the passage of the exhalations into the breathing pores. Poisonous repellents include coal tar and petroleum and many of their derivatives, such as naphthalene, carbolic acid, and kerosene. In other cases the olfactory sense is certainly the primary factor to be considered.

People long ago began to search drugstores for mosquito repellents and among the first ones tried were camphor and certain essential oils. By 1900 a large list of aromatics were being used as mosquito repellents, oil of citronella being the most promising. There are now numerous mosquito "chasers" on the market. Most of them are effective, although rather expensive, and perhaps in most cases not so efficient as those recommended by entomologists and medical men. They are usually composed of one or more essential oils combined with some heavy oil or grease and are to be applied as a lotion, spray, or ointment, depending on their consistency.

How do these substances afford protection against mosquito bites? One writer claims that mosquitoes are guided to a person in the dark by the odors emitted from the skin, and that all that is necessary is to disguise the smell of the skin. He concludes that the so-called mosquito repellents are not really repugnant to these insects but are effective merely because they change or disguise the attractive odors from the human skin. A second writer believes that these substances repel directly by emitting odors or vapors which are disagreeable or harmful to mosquitoes.

Before 1889 there were a few fly repellents on the market, but during the first decade of the twentieth century the proprietary preparations of this character had greatly increased in number. The two most important types of repellents introduced at this time were the sprays for the protection of dairy cows and the mixtures designed to prevent certain kinds of flies from laying their eggs in the wounds of livestock.

In the effort to prevent flies from laying eggs in wounds, where their larvae or maggots produce a disease called myiasis, much experimental work has been done. In the Southwest screwworm flies cause an annual loss of about $4,000,000 to the livestock industry. Since 1915 Bishopp and his co-workers in Texas have taken the lead in this research. One of the control measures recommended is the use of repellents, a very effective one for practical use being a mixture of one part furfural and 4 parts of pine-tar oil.

Repellents are included among the control measures for blowflies, tsetse flies, botflies, certain buffalo gnats or black flies, certain midgets causing sandfly fever, and a few beetles, moths, and other insects. In most cases, however, repellents, for various reasons, are not reliable remedies.

4. Do Plants attract Insects by Emanations?

It is well known that flower-loving insects are attracted to flowers by two senses—sight and smell; and the controversy as to which is the sense that mainly guides these insects in their quests has apparently been settled by the decision that sight is the more important. In spite of this it can not be stated positively that the whole truth regarding this is yet known, because the experimenters did not entirely control or eliminate the other senses while trying to prove the function of the sense in question. Since only a small percentage of insects are flower-loving, the results pertaining to them have only an indirect bearing on all the other insects which search for host plants. Certain members of this larger group of insects have recently been studied by the writer while making a fundamental investigation of plant emanations, attractants, and repellents. In order to be certain that no other sense aided the olfactory responses, a special apparatus was developed which practically eliminated or controlled all the stimuli except the olfactory ones. Economic entomologists have become more and more interested in this general subject and a study of the fundamentals underlying it would be of interest to all students of the interrelationships of plants and insects.

Briefly, the apparatus, called an insect olfactometer, consists of a specially constructed glass Y-tube (Fig. 13, *A*, A_2, A_3, A_4) through which insects pass from a dark chamber (*D*), being attracted by a light (*H*) suspended near the free ends of the forks of this tube. The dark chamber is attached to the base of the Y-tube, while a suction apparatus (*E*, E_2, E_3, E_4) to draw the odors through the forks is attached at the point where the base and forks unite. The principle involved is to attract the insects equally toward the entrances of the forks by the light stimulus, but when they are ready to enter these forks they are influenced unequally by the odors drawn through the forks, one fork serving as an attractive or repellent side and the other fork as the control side. The whole apparatus is so constructed and manipulated that the interfering factors are practically controlled, leaving only the olfactory responses to be recorded.

When testing the emanations of plants, the apparatus with the plant chamber (*C*) attached was assembled as shown in Figure 13, and the odorous air from the plant on the left and the non-odorous air from the control side on the right were drawn through the apparatus as indicated by the arrows. Emanations drawn through the apparatus from living potato plants could not be detected by the writer, but in every one of the 24 experiments conducted, each consisting of four individual tests, the beetles gave attractive responses, the highest individual test giving 81.2 per cent. (Fig. 14, *A*) and the highest average for four individual tests being 76.7 per cent.

Since potato beetles, when potato plants are scarce or entirely wanting, feed on the horsenettle, jimsonwood, tomato, henbane, and a few other related plants, all belonging to the potato family, the preceding experiments were repeated with some of these plants. The results obtained (Fig. 14, *B*) indicated that the beetles liked the emanations from these plants very little in comparison to those from potato plants, although in or near potato patches it is common to see these insects on one of them, the horsenettle.

When testing the water extracts and steam distillates of these host plants, the apparatus was used with the plant chamber disconnected, the extract or distillate being put in one bottle (Fig. 13, *B*) and distilled water in the control bottle (B_2). It was thus shown by a long series of experiments that potato beetles can be induced to respond to their food odors by subjecting them to the odors from these extracts (Fig. 14, *C* and *D*) and distillates. These results and those pertaining to the emanations give indisputable proof for the first time that plants (not flowers) attract insects by emitting odors.

After aerating the steam distillates of potato foliage (Fig. 14, *E*), potato tubers, horsenettle, henbane, and tomato plants for some time, odors from all of these distillates became attractive to potato beetles, and the writer could detect a common odor among them. This odor closely resembled that from boiling potatoes or from the juice of freshly cut potatoes, and might be called a potato odor. Since all these plants belong to the potato family, it would be interesting to know whether they possess a particular constituent or constituents emitting a common odor, as indicated by the responses of the beetles and by the writer's nose. If so, it is suggested that the chemist tell us what it is, so that we may use it in poisoned baits or in traps, thereby perhaps reducing the cost of controlling potato beetles, which must now be done by dusting and spraying the potato plants.

THE CHAINS OF PROMETHEUS

By Dr. BENJAMIN C. GRUENBERG
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WHILE every increase of knowledge means an increase of power, it means also an increase of sorrow. This is not to say that ignorance is bliss, or that wisdom is folly. It is only to recognize that knowledge does inhibit action, does dampen enthusiasm, does increase the burden of care. It is not necessary to defend knowledge, or its modern equivalent, science. But it is necessary for us to understand something of its nature and its limitations, of its dangers and its implications, as well as some of its concrete products and applications.

PROMETHEUS, REVOLUTIONIST

When Prometheus stole the flame from heaven he not only embarrassed the gods. He conferred upon man the most precious of gifts and set the pattern for all subsequent revolutions. This pattern consists essentially of violating established custom by means of a radical innovation that disturbs the complacency and self-esteem of the population and arouses the resentment of the authorities. In the course of time the novelty of any novelty wears off; and then the revolutionary device is no longer a novelty but part of the accepted order of nature, an integral unit in the eternal verities, in fact.

Consider fire. At one time this was an innovation, and a violation of the normal and divine order of the universe. For thousands of years, then, to play with fire meant not merely to incur the known risks of a partially controlled force, like hunting wild beasts at the risk of getting killed. It meant much more than that, and something quite different. It meant to trifle with magic, to pry into holy mysteries, to challenge the gods; it meant to tempt providence, to defy heaven itself. Nevertheless, the merits of fire gradually insinuated themselves into the consciousness of man. Throughout the ages countless eulogies have been pronounced in praise of fire, its virtues have been widely extolled, and it was earnestly defended against its enemies.

NOVELTY STALES

To-day, this strange force has become assimilated into our daily lives. It must now be a long time since any one has rushed to its defense or composed a poem in its vindication, or since, on the other hand, any one has seriously attempted to discredit fire as a treacherous friend, as an ever-present source of danger, and its use as contrary to the obvious purposes of nature and all the gods. We no longer fear that a wide distribution of strike-anywhere matches will increase the temptation to commit arson. Although the destruction due to fire amounts to hundreds of lives and millions of dollars in property every year, even children to-day accept fire as part of nature and of the orderly routine of life. We do still retain a few ceremonials that point to the primitive attitudes, but most of us do not take them very seriously even as ritual. What was once a solemn business calculated to keep us in communication with the gods through our high priests has degenerated into child's play or empty pageantry. We have become so thoroughly habituated and indifferent to the presence of fire that friends and foes alike have all but forgotten Prometheus.

WHAT PRICE KNOWLEDGE

The fire of Prometheus comes then to be considered a matter of course, and a valuable gift from on high. If now we accept the benefits of this wonderful process of oxidation, we must recognize also that, like every other advantage, this gift has carried with it serious dangers, whether we consider the material benefits of fire in the concrete, or the spiritual benefits that are symbolized by the torch. It is true that we do not have to burn our houses in order to roast our pigs, but we can not roast our pigs without losing many houses, and an occasional human life, in the process of acquiring skill and safety in the use of fire.

There are two points here for our consideration. On the one hand there are the unquestionable risks and dangers inherent in every form of force. The ancients had no practicable steam engines, but neither had they boiler explosions. You discover that mushrooms are good to eat, and that is clear gain. You discover only later that there are mushrooms and mushrooms; then there is wailing and sackcloth. That is to say, there is the danger of knowing, but knowing too little. On the other hand, there are the capacities for understanding and control and utilization inherent in the spirit of man. We can learn to distinguish one mushroom from another, we can learn to use steam without boiler explosions, we can learn to use horse serum without anaphylaxis. That is to say, there is the hope of clear vision and deeper insight. Whether in any given case mastery or disaster will be realized, or how much of each, constitutes the whole issue between fear and superstition and inertia and reaction on the one side, and science, vision, enterprise and progress on the other. And all this applies to many later gifts no less than to fire.

INNOVATIONS MUST DESTROY

Every new instrument whereby man has increased his control of natural forces has carried with it the possibility of destroying both human life and the things we value. The revolutionary thought or device often does violence to the things of the spirit as well as to our material possessions. We may be tempted to disparage the hostility to science by saying that the spiritual treasures which new ideas threaten are merely prejudices, merely superstitions; they are nevertheless precious to their owners, and essentially of the same stuff as the analogous beliefs and theories of our more enlightened colleagues. We may be tempted to sneer at the bungling crafts and the obsolete instruments of those whom new inventions displace; but the old crafts and the old tools are of vital significance to those for whom they have meant a way of living as well as a means of livelihood. Every innovation must meet the resistance and active opposition of a certain portion of the population.

THE COMFORT OF THE CUSTOMARY

To all people the familiar way of life, the customary, appears as the natural. It is natural, many people are certain, for traffic to pass to the right. In other countries, where the general level of intelligence is presumably as high as it is in this country, it appears to be natural to turn to the left. An attempt to obtain uniform practice, for reasons which seem to be good and sufficient to those who have studied the problem, is sure to be met with resistance. Now it is strictly in accord with human nature to acquire habits, as we may call them for short; but it is also in accord with human nature to resist every pressure to change habits. If it be proposed to have all turn to the right, the English and Austrians and Italians will present good reasons why they should not change—their practice goes back to times when the memory of man knows not to the contrary. If it be proposed that we all turn to the left, the Americans and Germans and French will offer equally good arguments why they should not yield; certainly they could not readily see why the obviously desirable uniformity should be obtained at *their* expense. All of us, however, will admit that it would be highly desirable for other people to adopt our customs.

COMMON SENSE

The customary and familiar are not only natural, but they accord with common sense. If we find peoples with different customs, it is evidence that they are queer. Yet, if they eat the hearts of their enemies with the absurd idea of thereby gaining courage, we eat celery, or drink celery compounds, to strengthen our nerves, or go to fish for brain food. If strange people curiously slaughter their animals with rituals and magic words, some of us are strict vegetarians for equally solemn reasons, or plant our acres according to the phases of the moon. With certain peculiar sects, respect is indicated by covering the hair; yet we consider it common sense for the male of the species to manifest respect for persons, monuments, churches or symbols by removing the head-gear. In any case, however, it seems to be common sense to do as we have always done.

For millions of people who have been brought up on chlorinated water, the treatment of water with chlorine for the purpose of destroying bacterial life is a matter of course, common sense. Of these same people, however, a considerable proportion will revolt at the suggestion of treating their water supply with iodin. They don't want their water "doped." The editor of a Seattle paper writes eloquently, "If some people want that stuff in their water, let 'em have it; but don't force it on the rest of us." In Minneapolis and in other cities, committees of cultured ladies and gentlemen protested that they wanted their water and their table salt just as nature intended it to be. There may be involved here a bit of the notoriously dangerous little knowledge: "that stuff" means to some people a dark purple or brownish substance, with a not very pleasant odor, whereas the "iodin" which the doctors propose to put into the water supply is a rather handsome crystal of potassium iodid that not one person in a hundred would distinguish from common salt, and that no person at all could discover through the senses after it was placed in the water. There may be good reasons for treating a community's water supply with iodin, and there may be good reasons against the proposal; but these reasons do not lie in common sense, they lie in a variety of technical considerations for which one needs special information, and perhaps special training also. At any rate, the basis for opposition in most cases is to be found in the violation of custom and prejudice.

IN PRAISE OF INERTIA

Any demand for a change in customs or usage is resisted by us not on the ground that we do not like to change our habits, but on the ground that the new proposals are in violation of common sense. That is to say, we are inert because we are inert, and we rationalize our inertia because our intellectual vanity requires justification of our conduct in terms of reason or sense. In many cases, also, the demands and proposals of innovators are offensive because they presuppose knowledge which is not shared by all, that is, knowledge which is not common; and we can not help resenting the insolence of those who set themselves up as superior.

NATURAL RIGHTS

Closely related to the rationalization of our accustomed behavior and values as being natural and in accord with common sense is the sensitiveness of the personality to any invasion from without. We insist upon our natural rights; we are all strong for personal liberty. Without searching too closely into the nature and sources of these rights, and without determining critically the sanctions of personal liberty, we are satisfied that our rights do somehow coincide with what is natural and proper. But personal liberty turns out very often to mean no more than our insistence upon our right to continue to do as we have always done. The dairyman who has established a life's routine in terms of producing and distributing milk in a certain way will resent as an invasion of his personal liberty and his natural rights the attempt of a health board to regulate the conditions under which he may continue his business efforts. The fact that his business is affected will complicate matters because he has the natural right to make a living, and as much more as he can, by the method which he has always followed, and which has always been tolerated as legitimate. Whatever reasons may be given by the health authorities for tuberculin testing, for pasteurization, for sterilization of equipment, for minimum fat-content, may mean something worthy to the health officer, or even to the ultimate consumer: to the dairyman these things all mean irritating interference with the natural and common-sense procedure that has been recognized as legitimate, even praiseworthy, from time immemorial, and infringements upon his personal liberty.

And Personal Liberty

Most of us become so thoroughly indoctrinated with reliance upon the familiar as absolute that we seem to be constitutionally incapable of entertaining new ways of thinking, or of tolerating strange ways of interpreting the facts of life. Under the circumstances we must always resist new ideas and we must resist also the methods by which new truths are dug out of the old earth. For those of us who can not understand the new concepts, who can not adapt ourselves to the demands of the new gods, opposition is natural enough. In a large proportion of cases the opposition is one of fear. After all, there is always danger in the unknown; and in the presence of danger caution is wisdom. After all, regardless of its merits and possible uses, fire *does* destroy houses and even human lives. More and more, however, hostility to the advancement of science and to the applications of science appeals not so much to fear as to the universal desire for freedom. And this, as I have tried to intimate, is in effect the right to do what one is accustomed to do, whether it is getting drunk or expectorating promiscuously.

A writer in Massachusetts reporting on the achievements and failures of the last legislature says among other things: "It is still the inalienable right of all typhoid carriers to infect others if they happen to prefer food handling to other methods of livelihood." There is reason to believe that this was writ sarcastic, and sarcasm always suggests the superiority complex. Yet in the minds of those who are threatened with the type of legislation discussed this is a serious matter that affects the very foundations of happy living—for the individual. Opposition to such legislation can be justified in terms of common sense—that is, the traditional and prevailing assumptions. We must be permitted to do as we have always done unless reasons to the contrary are overwhelming. But reasons to the contrary never are overwhelming—unless we know all that is involved, unless, that is, we come into possession of the new knowledge.

Knowledge a Hindrance

In the absence of knowledge impulses find free play without inhibition. It is this that constitutes the happiness of the infant; it is this that makes the idiot cheerful. It is the inhibitions of painful experiences, the inhibitions of conflicting impulses, that make knowledge and thought possible. And with every new addition to our knowledge and thought there appear new inhibitions, new obstacles to doing what we feel like doing. We may be throwing what we no longer need wherever we find it convenient to do so; the discovery that our neighbors can make their objections effective, or the discovery that refuse may become a source of injury or disease, must give us pause.

Science comes to be wicked because it threatens our liberties. To the degree that scientists are permitted to influence our customs and our laws, to that degree are we beset with regulations and restrictions and interferences with our natural—that is to say, our habitual—modes of life, with our happiness. It is for these reasons that science has become anathema, for those who do not understand its methods and its aims.

RESIGNATION TO NECESSITY

Most of us have learned to accept certain revolutionary innovations without violent protest. We agree to build our houses according to the building code. We agree to have our wiring done by licensed electricians. We have even moved away from our farms before the ploughing was finished because we were assured that flooding our land was necessary to save a city fifty miles away. It has become feasible, in most parts of the country, to get the public to cooperate in preventing the pollution of streams and bathing beaches. Several millions of our population have voluntarily assumed the restraints upon personal freedom implied in a knowledge of the hookworm's life-history. We are by no means unanimous regarding either the reliable knowledge or the standard practice in the matter of alcoholic beverages: there are in the situation elements of religious tradition and political dogma as well as of personal indulgence and puritanical bigotry. On the whole, however, civilized people the world over are accepting the restrictions that are implied in the mechanisms of the so-called scientific age with more and more resignation. They are voluntarily renouncing certain liberties in return for certain concrete benefits that the electricity and machinery offer them.

IN PRAISE OF IGNORANCE

In making application of the younger sciences, those that have emerged from a study of organic processes, the public is not so well prepared to renounce and to cooperate. People who pay rent can see why the building of tenements and the installation of plumbing should be regulated by law; but they can not all see why established industries should be regulated by law as to hours of work, or as to output of smoke and noise, or as to sex discrimination. Pedestrians can see why the state should restrict car driving or the erection of bridges to those who can demonstrate some degree of skill and proficiency in these arts; but they can not all see why the practice of the healing arts should be thus restricted. Healing is for too large a part of the population still akin to the miracles and magic of religious practice. "Many believe in divine healing," says a widely known preacher, "and therefore are conscientiously opposed to any man-made remedies in any form. Under our established principle of religious freedom, such citizens ought to be left free to follow their own conscience in such vital matters as vaccination." Those who drive cars can see why jay-walking should be prohibited but they can not all see the sense of the many personal and impertinent questions that the marriage clerk is likely to ask if they cross the state line.

KNOWLEDGE AND OPINION

In every case we are ready to submit to the prohibitions and compulsions of the mechanisms which we understand or control; in every case we are disposed to revolt against the constraints and checks of the instrument that we do not control or understand. The elaborate precautions taken to assure aseptic conditions in an operating room involve expense and delay, but they are burdens cheerfully accepted by those who know upon what they rest; to others they may be empty rituals. The silver nitrate which is in many states used in the compulsory medication of the new-born is another such interference with personal liberty and private opinion, it is another burden of expense; but it is accepted as a matter of common sense, or resented as a violation of natural rights, according to the kind and degree of enlightenment one has in such matters.

ABUSE OF KNOWLEDGE

Attempts of legislatures, and of others placed in authority, to impose restrictions of various kinds are likely enough in many cases to be arbitrary and to lead to abuse of power. It is possible to rationalize arbitrary acts and those that do indeed constitute abuses just as it is possible to rationalize our fears of the new and our dislike of authority. The fact that knowledge is power places those who know at an advantage; and naturally those of us who do not know become suspicious and resentful. It can not be claimed that either professional scientists, or those in a position to make use of scientific discoveries, have always considered primarily the welfare of their fellow citizens. It is possible to misuse science, just as it is possible to misuse any force; but that does not make science wicked, or its use a violation of nature's purpose.

KNOWLEDGE BRINGS FREEDOM

Those of us who are engaged in education, and particularly in the teaching of science, are in danger of becoming rather complacent. We are apt to rely too easily upon the widely accepted doctrine that knowledge is power, and *ipso facto* of benefit to mankind. We take for granted the adage that truth will make us free. This assumption is seldom challenged and very seldom do we ask ourselves just how it is that truth brings freedom, or what kind of liberty it is that truth insures. Neither the votaries of truth, or of its modern substitute, "science," nor the obscurantists and intuitionists are entirely wrong—or entirely right. Man's ability to discriminate among phenomena that are superficially alike, his ability to doubt and to question, his ability to look two or three or a million times to make sure, his ability to experiment, all those things about man that differentiate him from other anthropoids and from all other living things, have made possible an accumulation of reliable facts, and an elaboration of workable theories, which compel a form of living that is anything but "natural." The increase in knowledge has increased productivity of economic effort and so has increased leisure. It has lengthened life, and so has made available increased leisure during those age periods in which men and women are most concerned with the value of time and most skilled in the use of time. It has made possible a rate of transportation and of communication which is beyond any but the wildest fantasies of earlier times. In these and related ways science has increased our freedom by giving us more power, more time and more scope for fulfilling the heart's desire.

AND NEW RESTRICTIONS

With each addition to man's equipment there have come, however, a host of restrictions which to the uninitiated seem arbitrary and disproportionate to the alleged benefits. Thousands of people in all parts of the country will clamor on the slightest provocation for raw milk, when science recommends pasteurization; but neither the producer of milk nor the consumer is any longer free to follow tradition or common sense. "Do Not Spit" is still an injunction that for many people involves merely a matter of taste, about which we are advised not to argue.

Improved and cheapened means of transportation, with increased leisure, tempt us to travel abroad; science, that is, would free us from certain types of provincialism. We find, however, that in addition to the political restraints of passports and visas, which are the very embodiment of ignorance and supersition, we have to submit also to quarantine restrictions and vaccination requirements, and even to the discomforts, not to say humiliation, of medical examinations—which are supposed to be the very embodiments of light and learning.

The more we learn about the obscure forces and microscopic organisms and invisible processes, the less freedom have we to do as our impulses direct or as our traditions demand. From the disposal of bodily or domestic refuse to the manufacture and sale of various commodities, more and more of our activities come to be regulated and restricted by considerations entirely foreign to the common sense of our fathers and to our convenience and aspirations. When Prometheus was finally unbound it is certain that his chains were bequeathed to those who would use the stolen fires. Apparently we can not have one without the other.

EDUCATIONAL NEED

Scientific knowledge has accumulated faster than the general population can assimilate it. Moreover, new knowledge is always the discovery of specialists, so that at every point all but a very few must remain in outer darkness. We must take a large part of the liberating truth on faith. It is not enough, however, to tell the world that iodin is of value in certain cases as a preventive of simple goiter; the world ought to know how that was found out. It is not enough to teach that toxin-antitoxin does do whatever it is supposed to do: those who, for any reason, oppose its use can speak even louder. It is necessary to take the public into our confidence and to tell it how we have come to know. And increasingly, the diffusion of new knowledge devolves upon agencies outside the schools.

From the point of view of acquainting every new generation with the accomplishments of the past, both as addition to knowledge and as improved skill in the further conquest of the universe, it would seem insufficient to emphasize merely the concrete achievements that science has made possible and that every simple mind can value to a degree. It would seem important further to carry into our teaching an appreciation of the cost of science. And this cost must be made clear not merely in terms of the devotion—and frequently the sacrifice—of those who dedicate themselves to research, but also in terms of the inevitable restraints that every new technique imposes.

Masses in the future will have to learn what only a few have learned in the past, namely, that the attainment of truth is a continuous process and never an accomplished fact; that with every gain there comes a new set of inhibitions. It is no paradox to say that the liberations made possible by the truths which we know as science are made possible by self-imposed prohibitions and compulsions. The most difficult conditions which advancing science imposes upon us is that of starting each day prepared to scrap some of the cherished beliefs of the past. Advancement of science means not only deriving new power and new freedom out of new insight; it means also the acceptance of new disciplines, and new obligations, new restraints upon our impulses and prejudgments.

We can not have the torch without the chains.

THE HUMANIZING INFLUENCE OF PESTILENCE[1]

By T. WINGATE TODD, F.R.C.S. Eng.

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"TOWARDS evening when, according to Jewish belief, the gates of Heaven are shut, and no prayer can then obtain admittance, I heard a voice, with a ripple of tears that were never wept by human eyes. It was the death rattle of a soul sinking down dead tired at Heaven's gates." Few passages can equal and none excel these words of Heine to depict the desolation of the human heart of which plague has ever been the supreme affliction.

"And Moses said unto Aaron take a censor and go *quickly* unto the congregation and make an atonement for them: the plague is begun. And Aaron took as Moses commanded, and *ran*, and stood between the dead and the living." So there hangs on my tongue's end the greatest romance of medicine in the combat and overthrow of pestilence. The most human document relating thereto was written in 1485 by Bishop Bengst Knutsson, of Västerås in Sweden, a versatile man, physician to boot, trained at Montpellier. It is the first book printed in London with a title page, for printing was a very new method of reaching the people in those days. The first press had been set up in England less than a decade when our good bishop brought out his work. And his opening salutation in its vigor and benevolence sounds like the fanfare of the heralds of good tidings. "At the reverence and worship of the blessed Trinity and of the glorious virgin Saint Mary and the conservation of the common weal of all christian people, as well for them that are whole as for remedy of them that are sick." I should like to have met this physician of Montpellier, who in his struggling days wandered from house to house, as he himself tells us, penniless like those poor patients of his who could not escape, with loving kindness in his heart, the inspiring confidence of courage in his voice and a sprig of sweet smelling herbs in his hand. He was indeed the type of physician who plucks the jewel from the head of adversity and extracts his staunchest hope from the tragedy of disease.

They were great days these, the later Middle Ages. It was already three hundred years since Christendom awoke out of its lethargy. The stonework of Western Europe which rose fresh and white after the stimulus of the Crusades, with its pointed Gothic arches, was now weathered and old. The University of Paris and the Schools of Oxford dated back almost as far. Saint Bartholomew's hospital was three centuries old already. It was a hundred years since the Peasant's Rebellion in England had changed the face of society and the suppression of the Jacquerie in France had planted the seeds which burst into life much later in the French Revolution. It was a period of ease and the zenith of philosophy. Mantegna was engraving on copper. Donatello was reproducing in bronzè "the anatomy of the miser's heart.'' Leonardo was inscribing in pictorial form the new anatomy. In Ruskin's terms these men were polluting their art with the science of the sepulchre. The men of that day looked upon themselves with very much the same satisfaction that we look upon ourselves in this enlightened age. Wonders were developing with dazzling rapidity, and though many held the crack-brained Columbus to be a fool it was but a few years before the vision of the New World burst upon their astonished gaze. ''What does the fellow say,'' wrote Luca Sarto, ''but that the world's a globe—that it is shaped like a huge tart and is plattered in space. But also this tart is always spinning, and what lies eastward on the platter whirligigs to west. It is blasphemous coggery. This Christopher Stand-on-His-Head ruffles me.''

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[1] The author has made every effort to secure accuracy of essential fact and faithfulness of interpretation in this study, but he has not hesitated to draw freely upon writings such as those of William Morris, Filson Young, Hilaire Belloc and Charles Brooks to give the atmosphere and flavor of the times.

There is nothing which illustrates better the pinnacle of confidence which was attained by philosophy in the Middle Ages than this fact that a poor man, in a strange land, without knowledge of the classics or the Fathers, having no other argument than his own fixed belief and some vague tales about bits of wood and shipwrecked mariners, should be able ultimately to secure the influence and funds for taking a flotilla right out into the Sea of Darkness and down that curving watery slope up which none ever climbed before.

Yet at the heart of all this prosperity and splendor and activity in thought and art there was a canker, the canker of pestilence. A century and a half earlier, creeping insidiously along the Mediterranean shore, the basilisk had wormed its way into Europe, blasting everything in its path with its poisonous putrid breath.

Upon a morning in 1348 Boccaccio in Florence, looking from his window, saw two hogs rooting among the rags of a poor man just dead, and shaking them about in their mouths, ''when they both turned round and died on the spot.'' The sickening rats rushed from their holes and crevices in troops and ''issuing on to the floors sprang continually upwards from their hind legs as if they were trying to jump out of something.'' Penitent and confessor were borne together to the same grave and the funeral earth, chapped and ghastly, bulged over her new buried corpses.

Petrarch, like his friend Boccaccio, an eye-witness of the Black Death in Italy, foresaw the inability of future generations to imagine the empty houses, abandoned towns, fields crowded with dead, the solitude of the world. ''Is it possible that posterity can believe these things,'' he writes, ''when we who have seen them can scarcely believe them.''

The black death arrived at the critical moment when English social customs were maintaining with difficulty their traditional form. The problem of villeinage was occupying the public mind. There was no land hunger in those days. The towns had not yet begun to be the dominant factor in civilization. The worker was land bound and sought to be free. So when after 1348 his numbers were reduced by half, in spite of the Statute of Laborers, wages were permanently raised and freedom of migration was secured for the hinds of the manor. As the land owners died and estates fell in, the new yeoman and farmer class, afterwards so powerful in the fifteenth century, grew in strength by the accumulation of recruits from below. The business of the courts greatly increased and pettifogging lawyers, hated by the peasantry, swarmed over the land, ''men who had no souls but only parchment deeds and libels of the same.'' The impetus given to the workers developed the trade guilds of the towns. And so the entire structure of society was convulsed. Settlement awaited the Peasants' Revolt of 1381, but though this was suppressed, the humanizing elements which leapt out of the pestilence could not be defeated and the modern social order struggled at last

into the position in which it remained secure until these troublous times of ours. These were not men of a strange race or culture. The time, though distant across the centuries, is one with ours. And we also can be stirred as were John Nameless and John the Miller and John Carter that early summer evening in 1381 at Mitcham Green, when the reflections of John Ball fell softly on their listening ears. How "men fight and lose the battle, and the thing that they fought for comes about in spite of their defeat, and when it comes turns out not to be what they meant, and other men have to fight for what they meant under another name." "John Ball greeteth you well all and doth you to understand that he hath rungen your bell."

But, intermittently, from that year onward the Black Death scourged all Europe for three hundred years and calamity marched step by step with progress.

The theory of contagion gradually developed itself in the public mind, and by the sixteenth century became the basis of legislation for protection, not of the people in general, but of the court. However, specific measures quickly followed for isolation of the sick and protection of the populace.

The infected house was shut up with a large red cross and "Lord have mercy upon us" painted on the door. Watchmen, attending day and night, prevented any one going out or in except physicians, nurses and searchers prescribed by authority. These precautions were to continue, as the edict had it, until a month after all the family was dead or recovered.

Progress is slow to start and when it moves is apt to trample human hearts. So to the prisoners in the house, "strangers," as Mead wrote in his famous discourse (1720), "to everything but the melancholy sight of the progress Death makes among themselves," "Lord have mercy" must have seemed a curse and the four walls of their prison the very jaws of the tomb itself.

Of the last great plague in England, that of 1666, the newspapers of the day were full. Extracts from these were thrown together by Daniel Defoe, of Stokes Newington, in the form of a journal. This Daniel Defoe, whom we know so much better because he learned the adventures of Alexander Selkirk and went to school as a boy with another little lad called Timothy Crusoe, was a kind of combination of H. G. Wells and Bernard Shaw. They made him church warden knowing that as a dissenter he would rather pay the fine of ten pounds than assume office. Vividly and faithfully does Defoe tell of the people crazed by constant communion with unspeakable death dashing from their houses to end their life in the Thames and so escape the worse horror which drove them on.

Even the incorrigible Mr. Pepys breaks away from his vainglorious jottings to recount how there appeared before himself as magistrate "a very able citizen in Gracious Street, a saddler who had buried all the rest of his children, himself and wife now being shut up and in despair of escaping, who did desire only to save the life of this child; and so prevailed to have it received stark naked into the arms of a friend who brought it to Greenwich, where we did agree it should be permitted to be received and kept."

So in the course of time humanity prevailed. Mead, in 1720, advocated the abandonment of these terrible measures and proposed instead the establishment of hospitals outside the towns and the isolation of cities rather than of homes. It was Mead who persuaded Guy to found the hospital which goes by his name. He was a man of unbounded hospitality, who spent his afternoons in a lucrative high-class practice and his mornings prescribing for patients whom he had never seen, at half guinea fees, on the written or verbal reports of apothecaries. Mead's reforms were bitterly assailed and the next year nullified by act of Parliament. But of all the hard things said of Mead none surpasses in vigor or in scorn the invective of Noah Webster, the lexicographer, who set to work with a mind enlightened by the sources of words to seek the origin of pestilence. An ill-humored fellow, this Noah, who must have suffered from some kind of duodenal irritation. "Sound potatoes from the market," he writes, "perished in my cellar in thirty-six hours." So from this he goes on to larger issues. "In the United States, everything that has been done hitherto in the construction of cities, is in imitation of the old European mode, and of course is wrong." To such sweeping generalizations may a bad potato lead. Nevertheless even to Noah pestilence was a blessing in disguise, for it "humbles the pride and arrogance of man, by creating in his mind a perpetual dependence on divine power; in short it creates and preserves that sense of obligation and accountability to God which is the germ of piety and moral excellence."

But all journeys end in the twilight and the angelus interceding for preservation from pestilence closes the day. "Sweet scent," writes Luca Sarto, "wards off the plague better than the killing of a hundred Jews."

So I would hark back to my bishop, counselling the rich to leave town, breathing comfort and hope for the poor who, bound by circumstances, may not escape from the overcrowded city. "To be merry in the heart," he says, " is a great remedy for health of the body. Therefore in time of this infirmity beware ye dread not death, but live merrily and hope to live long." Of all documents on the pestilence this is the most moving and the most human. It is the physician as counsellor and sympathetic father-confessor who can see beyond the veil, like John Ball, the hedge priest of 1381, that "he who doeth well in fellowship shall not fail, but in days hereafter shall he and his work yet be alive and men shall be holpen by them to strive again and yet again."

BOTANICAL EXPLORATIONS IN THE ROCKY MOUNTAINS—SELWAY RIVER

By Professor J. E. KIRKWOOD
THE UNIVERSITY OF MONTANA

THE Bitter Root Mountains extend from Lolo Pass south to the head of the West Fork of the Bitter Root River, a distance of about seventy miles. They parallel the course of the river, which flows north, joining the Clark's Fork of the Columbia near the city of Missoula, Montana. The crest of the Bitter Roots forms part of the boundary between Montana and Idaho. On some of the older maps the Bitter Root Range is shown as extending from the Clark's Fork River to Yellowstone Park, but Lindgren's report on the geology of these mountains, published in 1904, defines the range as above given on the basis of its geological structure.

The Bitter Roots are a rugged and picturesque range, especially toward the southern end, where a lofty and serrated skyline of sharp peaks and castellated ridges rises as a forbidding barrier. Trapper Peak, southwest of Darby, is the highest point, reaching 10,175 feet, while other summits of 9,000 or more occur the whole length of the range. Passes are found here and there at elevations of 6,000 or over, and Lolo Pass is notably low at 5,400. The eastern face of the range is steep, cut by deep and numerous gorges, and rises from the Bitter Root River at an elevation of from 3,300 to 3,600 feet to the summit twenty miles more or less to the west, while the other slope descends by more gradual degrees to the Clearwater country with an average elevation of between 5,000 and 6,000 feet.

The Bitter Root Mountains lie athwart the prevailing winds of the region which come from the west and southwest. These are the rain-bearing winds, resulting in heavy precipitation on the windward side and correspondingly lighter rainfall on the area lying east of the range. The Bitter Root Valley, as a matter of fact, is one of the driest valleys of Montana, with an average annual precipitation of less than eleven inches. The streams flowing eastward from the summit are numerous but short and of small volume, but those flowing to the west converge into two rather large rivers, the Lochsa and the Selway, which are the main sources of the Clearwater, a strong affluent of the Snake.

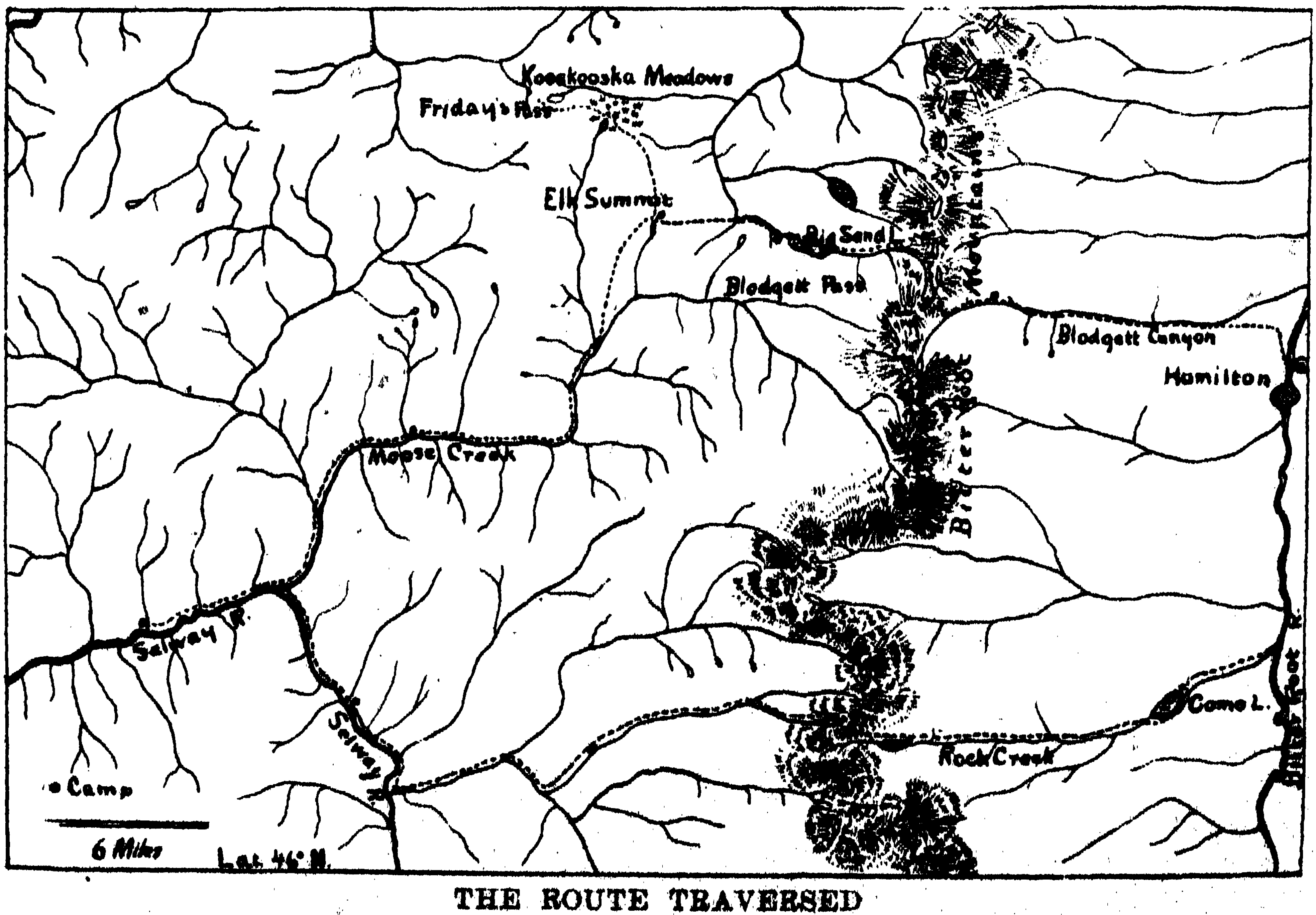
The difference in the precipitation and the conception of the Bitter Root Range as a potential barrier to the eastward movement of species led to the formulation of plans tq examine its flora with two objects in mind: first, the floristic; and second, the distributional aspects of the vegetation. Pacific Coast species of the humid areas of Oregon and Washington are plentifully represented in the favorable localities on the western slope of the northern Rockies. It is of interest to know what part they may have in the flora of the Bitter Roots.

This program involved the crossing of the Bitter Root Range and the traverse of an extensive wilderness little known, except to a few scattered settlers, occasional hunters and a limited number of employees of the U. S. Forest Service. The effort to do this occupied parts of two seasons and took the writer over some three hundred miles of trails. Saddle and pack-horses were the only means of transportation in a section far removed from even the roughest wagon roads. The Bitter Root Mountains proper lie along the eastern border of this wilderness and shut it off from the older settled regions of western Montana. To the west from the Bitter Root summits it is close to one hundred miles to Kooskia on the Clearwater, the nearest important settlement on the Idaho side. The area, however, to which attention was directed in this brief survey amounts roughly to between 3,500 and 4,000 square miles, including the Bitter Root Mountains and the country thirty miles or more to the west and northwest. The results of this study will appear in a later report. This account will present some of the general aspects of the country and incidents of the trips.

We outfitted at Hamilton, Montana, and secured the services of Ned Hobbs, of that place, as packer. Mr. A. N. Hobbs, father of the packer, volunteered as cook. Mr. Dan Nyffler, an old friend of Ned Hobbs and his guest at the time, also accompanied the outfit and assisted efficiently in the packing. In addition, the personnel of the party consisted of Mr. J. W. Severy, instructor in botany at the State University of Montana, the writer and his son, Edward.

On the morning of the 23rd of August, 1923, we left Hamilton and turned our faces toward the Bitter Root Mountains, which seem to rise almost from the outskirts of the town. Blodgett Canyon opens like a vast portal with perpendicular walls of granite admitting to the secrets of a beyond, to us wild and unknown. In spite of the awe of its magnificence and mystery, our spirits were high and thrilled with eager interest at the prospect before us for the next three weeks. No hint of sinister significance reached us or any forecast of this ill-starred expedition.

Views of fences and farms were soon left behind as the trail began to thread its way along the bottom of the canyon



THE ROUTE TRAVERSED

THE BITTER ROOT MOUNTAINS AND PARTS OF THE BITTER ROOT AND SELWAY DRAINAGE.

BITTER ROOT MOUNTAINS FROM THE WEST

beneath the beetling cliffs, with Blodgett Creek roaring down its rock-strewn course. The trail rose steadily and we were soon out of the yellow pine belt and began to see groups of lodgepole pine and aspen. Subalpine fir and Engelmann spruce then began to appear along the creek. Huckleberry (*V. membranaceum*) and snow-brush (*Menziesia ferruginea*) and clumps of alder (*A. sinuata*) around springs indicated our passing into the main timber belt or montane zone. The day grew hot and we stopped frequently to refresh ourselves with the clear cold water that rushed by at our feet.

The pack train moved steadily onward to the tinkling of bells and the shouts of the packers. Progress was slow, for of all trails encountered before or since over several years, the Blodgett Trail is the worst. Granite boulders tumbled from the cliffs above covered the canyon floor. The horses with their heavy packs stumbled and scrambled over them in imminent danger of breaking legs or pulling off shoes. They labored and sweat and puffed as they advanced under the patient guidance of the packers. Even the unburdened saddle-horses and their riders, now afoot, found enough to do. As the canyon narrowed, we traversed the talus of cliffs or the debris of avalanches thrown confusedly into the bottom of the gorge.

The aim had been to gain the high meadows near Blodgett Pass the first day. But as the afternoon drew on there were still several miles to go. Horses and men were tired, so camp was made with only twelve miles accomplished. Between the trail and the stream on an inviting little flat our first camp was pitched. The trail had risen 2,200 feet above Hamilton but seemed farther from the crest than at the start On either side, in austere and rugged grandeur, towered mighty walls to nearly 3,000 feet above the camp. Around us the somber fir and spruce cast deepening shadows, while the sun's declining glow gilded the lofty peaks. The freshness of early summer was here in leaf and flower, where neither the hot drouth of the valley nor the early frost of autumn had yet reached them.

In the midst of this contemplation sounded the call to dinner. Out of the medley of cans and bags, the magic of the elder Hobbs had conjured a feast to

A FOREST OF YELLOW PINE (*PINUS PONDEROSA*)
COMMON VIEW ON SOUTHERN EXPOSURES IN THE BITTER ROOT MOUNTAINS.

which we now addressed ourselves with appetites born of that laborious trail, of the scented forest and the exhilaration of the evening hour.

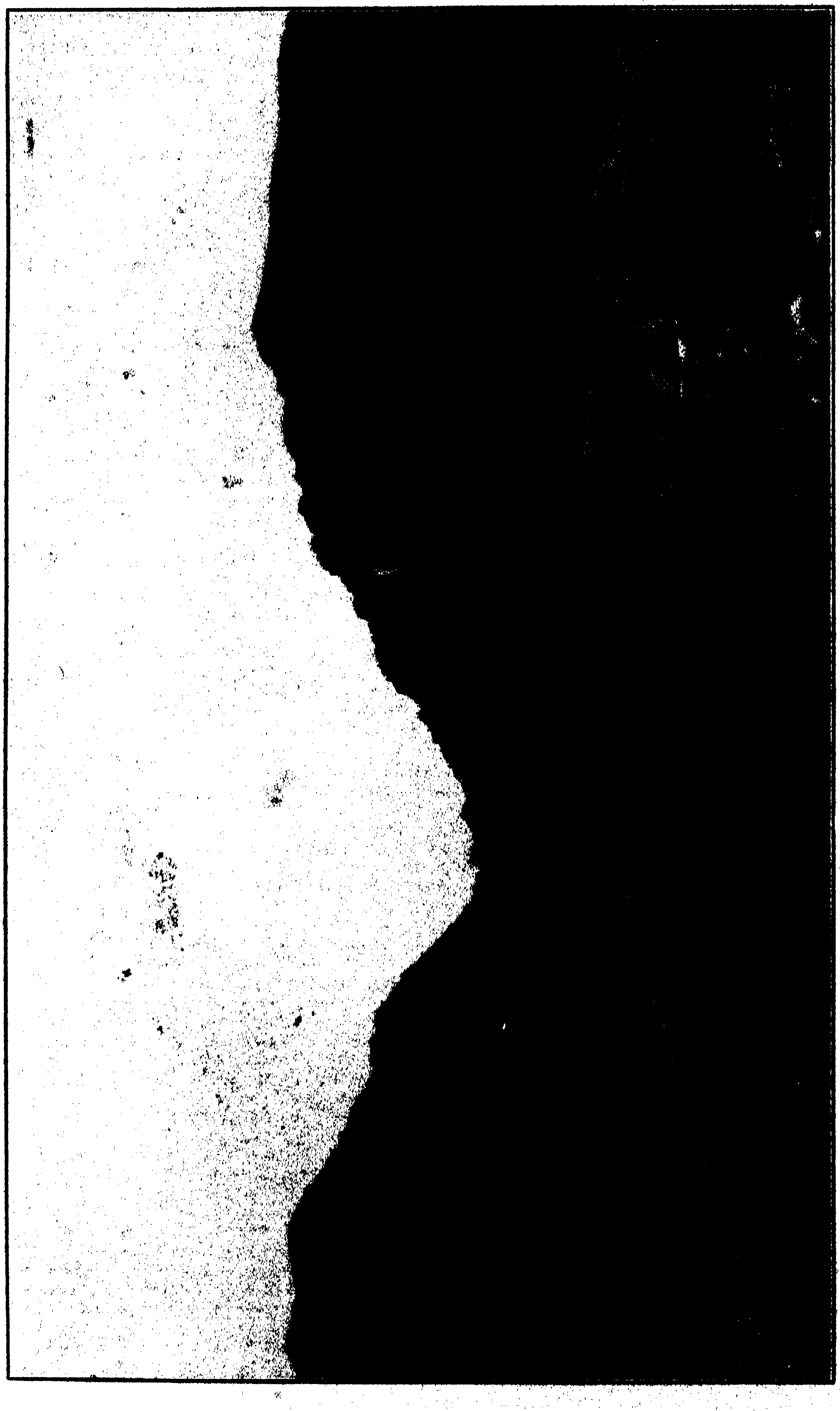
Day awoke in the east and the camp was astir ere the sun's level rays had brightened the lofty crests above us. Breakfast was on, the horses were coming in, bedding was rolled and packs made up. When our saddle-horses were ready three of us took the trail, leaving Ned and his father and Dan to pack the horses and follow. This was our usual procedure, which suited all concerned. It gave us in the lead more leisure to make collections, notes and photographs, and we were out of the way of the packers, whose operations we could not materially aid.

A few miles above camp the trail turns abruptly from the creek toward the high northern wall of the canyon. There was no mincing matters here. The summit had to be carried by direct assault, and up we went. First straight ahead over the lower slope and then, as it grew steeper, we swung alternately right and left in a series of sharp "switchbacks" that carried us rapidly far above the floor of the valley. The sharp spires of the firs rose among the spruces along the creek and dwarfed into insignificance as we ascended. A cliff-like wall rose above us, and along the face of this the trail was carved. From this point a panorama spread wide before us. We were now out of the forest and could see far with uninterrupted vision. Our canyon where we had left it began to turn in a broad sweeping curve toward the south, where it took its source in a lake nestled among the peaks. Its walls of bare and scarred granite presented a deep, rounded, glacial trough. Here the north and west wall of Blodgett Canyon forms the main crest of the Bitter Roots. On and on as far as the eye could reach was a wildly tossing sea of crags and peaks. Down the canyon to the east lay our trail of yesterday—somewhere deep in the chasm among the spruces and firs and tumbled boulders—and away out beyond was the Bitter Root Valley. But the pack train was coming on; we could see them emerging from the woods toward the ascent and knew that our time for viewing the landscape was limited. We turned reluctantly from the vision and addressed ourselves once more to the ascent.

The trail crosses Blodgett Pass at 6,500 feet. Right here we found *Rhododendron albiflorum* and the little *Luetkea pectinata*, both unreported from the Bitter Root Mountains. The top of the range here is a very narrow, rounded ridge. One emerges from the ascent and in less than twenty paces begins a sharp descent on the other side. He passes from a treeless slope suddenly into a luxuriant forest of fir, pine and spruce. Corkscrew-like the trail descends for a few hundred feet and then on a more moderate incline emerges on a beautiful subalpine meadow gorgeous in its array of deep blue gentians (*G. calycosa*). The sound of a little stream comes to our ears. A trench in the meadow sod, fringed with low willows, lush grasses and sedges, carried clear, cold water, dropping rapidly over its stony bed, gaining at every step, on its way to Big Sand Creek. Our trail follows this stream and we descend rapidly. The pack train has already passed us, so we

ENTRANCE TO BLODGETT CANYON

IN THE BITTER ROOT MOUNTAINS. ON THE LEFT, WESTERN YELLOW PINE (*Pinus ponderosa*). SHRUB IN BLOOM IS SERVICE BERRY (*Amelanchier alnifolia*).



—Courtesy of Johnson Studios, Hamilton, Mont.

BLODGETT CANYON FROM THE BITTER ROOT VALLEY keep moving except as we pause to gather specimens too good to leave. The trail is deeply gullied by flood-waters and progress is slow, but withal it is better going than yesterday.

With decreasing elevation we come onto flatter, drier ground where the lodgepole pine is dominant, and for hours the trail, now much better, leads us steadily westward towards Big Sand Lake. This beautiful body of water lies like a silver mirror fringed by green forest. The silent fir and spruce hedges it round and it seemed as if its placid bosom was never stirred by a passing breeze. We wanted to linger at this enchanted spot, but the shadows were lengthening and there was some distance yet to go before we could find feed for the horses, a necessary consideration at every camp.

The problem of supporting horses on a trip of this sort is an ever-present one. In an open prairie or meadow there is usually little difficulty; the native grasses of many species furnish excellent forage and animals feed contentedly without straying far on such pastures. But most of the area we were now traversing was forested. The forest offers little feed. Most of its plants are lacking in nutritive value. Few grasses occur. The creek bottoms with their thickets of willows and other shrubs are little better than the upland pine forests. Bogs and young meadows around the shores of lakes produce mostly coarse sedges which, although some of them are eaten, are rather unwholesome. In burned areas the growth of weeds and browse is also of little value, and the amount of fallen timber makes difficult access to what is edible. Consequently feed is limited mainly to open glades and meadows where grasses abound, and these are found in their best condition at higher elevations. Horses will not stay on poor feeding grounds and, though hobbled, will sometimes wander miles away during the night, necessitating arduous exertions on the part of the wrangler and entailing delays which are inconvenient and sometimes expensive. Picketing is always inconvenient and risky and, on poor feed, impracticable. Hence the packer must turn his horses loose and trust to bells, barricades and other devices to insure his finding them again. One of the vicissitudes of this trip was the scarcity of feed and the consequent difficulty of keeping our horses within reach. Constant vigilance night and day was required to avoid losing them while feeding and the length of our marches and the duration of our sojourn here or there were dictated by this contingency.

The next day the trail held to the course of the stream for a few miles and then swung to the west, rising along a south-facing slope and burned area to an open green forest on top of a ridge near 7,000 feet. We then began to drop down into a shallow basin and at noon pulled up at Elk Summit Ranger Station. Here is one of the most beautiful and extensive of the mountain "parks," embracing a hundred acres or more, partly level meadow, partly gently rolling slopes dotted with clumps of spruce and fir. Grass grew luxuriantly, and a little stream flowing from a small lake wound its way between low banks. This ideal location lay on the Lochsa-Selway divide. To the east water flowed to the Big Sand and thence to the Lochsa, to the west into Moose Creek and the Selway.

After a brief call on Ranger Bell we pushed on northward to Kooskooska Meadows, about seven miles farther. One of the many trails leading out from Elk Summit was pointed out to us. It led up a gentle slope through an old lodgepole burn. By insensible degrees it passed from the lodgepole pine into the

BREAKING CAMP AT ELK SUMMIT

TREES IN THE BACKGROUND ARE SUBALPINE FIRS.

white bark pine and its carpet of wood rush and clumps of purple mountain heather (*Phyllodoce empetriformis*) and Labrador Tea (*Ledum glandulosum*) and we knew that we were now near 7,000 feet elevation. This elevation of land proved to be a long narrow ridge from the vantage of which we were afforded an excellent view of the west side of the Bitter Roots whose rugged summits formed the eastern skyline. St. Mary's Peak, the Heavenly Twins, El Capitan and Trapper rose in their magnificence in a panorama nearly seventy miles wide across the deep canyon of the Big Sand.

From this ridge the trail dropped rapidly through an open and partially burned forest and emerged at the edge of a wet bog where pools of water alternated with islands of rush and sedge and with the white plumes of the cotton-grass (*Eriophorum*) waving in the breeze. Kooskooska Meadows was originally a small lake formed either in a natural depression or through the work of beavers. Silt and sand carried in by streams and the encroachment of vegetation have resulted in a level area of many acres of heavy turf formed of grasses, sedges, shrubs and other plants, traversed by meandering watercourses, whose channels are often treacherously hidden under overhanging vegetation. Its varied surface displayed different steps in the succession toward the mature stage; first, the aquatic sedges and other plants; then the drier areas occupied by grasses; then the shrubby vegetation. Here also the fir and spruce are dominant and where not killed by fires form a thick and somber forest skirting the edges of the bog. This was what the elder Hobbs deprecatingly called a "moose bog," in allusion to the poor prospect it presented for his horses.

Two days were spent at these meadows. One was devoted to a side trip to Friday's Pass, five or six miles from camp. A couple of saddle-horses were requisitioned, and the writer in company with Mr. Severy set out over the trail that led, *via* this pass, to the Lochsa Canyon. The whole of the distance lay through a heavily burned area, which presented little of interest except as we neared the pass where some rich subalpine meadows furnished a collection of *Luetkea*, growing in dense flowering mats on a southern exposure. *Campanula Parryi* and species of *Hypericum*, *Senecio* and *Arnica* were also conspicuous in full bloom.

The pass has an altitude of 8,000 feet. Here the trail crosses a grassy glade and descends abruptly toward the Lochsa. A belt of green timber which had escaped the fire consisted mainly of white bark pine (*P. albicaulis*); but a little to one side and above the pass we came upon Lyall's Larch (*L. Lyallii*), the first and only specimens found on the Selway trip.

Beyond the pass and below the peak lies the chain of little Wind Lakes. They are several hundred feet below the pass and were reached by us with some difficulty, clambering down over cliff and talus. They lay in open meadows fringed by grasses and sedges. Our time was short, so after making hurried collections we turned our faces toward camp, well satisfied with the day's experience.

Returning to Elk Summit we established ourselves for a day's stopover in this delightful spot. Here we made good use of the time and fair weather in drying blotters and getting specimens advanced in the curing process. A few things were added to our list, but the lateness of the season necessarily limited the collection.

From here we turned our faces toward the Selway River, distant some twenty-five or thirty miles. The land fell away to Moose Creek in a steep descent through a narrow gorge. This being a difficult and impracticable route is probably the reason why our trail took us over a high ridge to the north of the canyon and then down by a winding way

SUBALPINE MEADOWS AT ELK SUMMIT

TREES WITH THE SPIRE-LIKE CROWNS ARE SUBALPINE FIR (*Abies lasiocarpa*). OTHERS ARE PRINCIPALLY ENGELMANN SPRUCE (*Picea Engelmanni*).

WHITEBARK PINE (*PINUS ALBICAULIS*)

IN FRIDAY'S PASS. ALTITUDE 8,000 FEET. GRANITE BOULDERS.

to the stream some miles below. The westward slope of this mountain was notable in the presence, size and frequency of certain species not met before. The grand fir (*Abies grandis*) and Cascara (*Rhamnus Purshiana*), both partial to moist conditions and moderate temperature, were especially worthy of mention, and the mountain laurel (*Ceanothus velutinus*) attained a height of six to eight feet as against the height of two feet seen in the Bitter Root Valley and elsewhere in dry places in Montana. All these species grow luxuriantly in the Coast Mountains of Oregon and reach larger dimensions than anywhere in the Rockies.

From the foot of the mountain the trail follows Moose Creek along the bottom. This tributary of the Selway heads to the south of Elk Summit and becomes a considerable stream ere it joins the river. Along this stream we soon came upon another expression of the coast conditions in a most interesting and pleasing way. For several miles our trail led through a magnificent stand of arbor vitae (*Thuja plicata*). The huge trunks of these trees, with diameters of three to six feet, rose in tall columns supporting a canopy of foliage through which the sunlight scarcely penetrated. It was practically a pure forest and so dense that few plants grew beneath it. Only the maidenhair fern, which grew in profusion, could really be said to be successful in this deep shade. There formerly were fifteen or twenty miles of this forest before the fires swept through this section. Now about six miles is all that remains untouched. Emerging from the cavernous depths of this green belt into the desolate and weedy burn led us to an acute realization of the loss to which we were subject through forest fires.

About four o'clock found us at Maple Creek, where we camped for the night. Hours of travelling through the hot sun over a dusty trail made the cold, clear water look good to us, so we stripped and plunged into its icy flow. A few minutes only, but it refreshed us greatly and we dressed and set vigorously about our work of preparing the day's collections from along the trail.

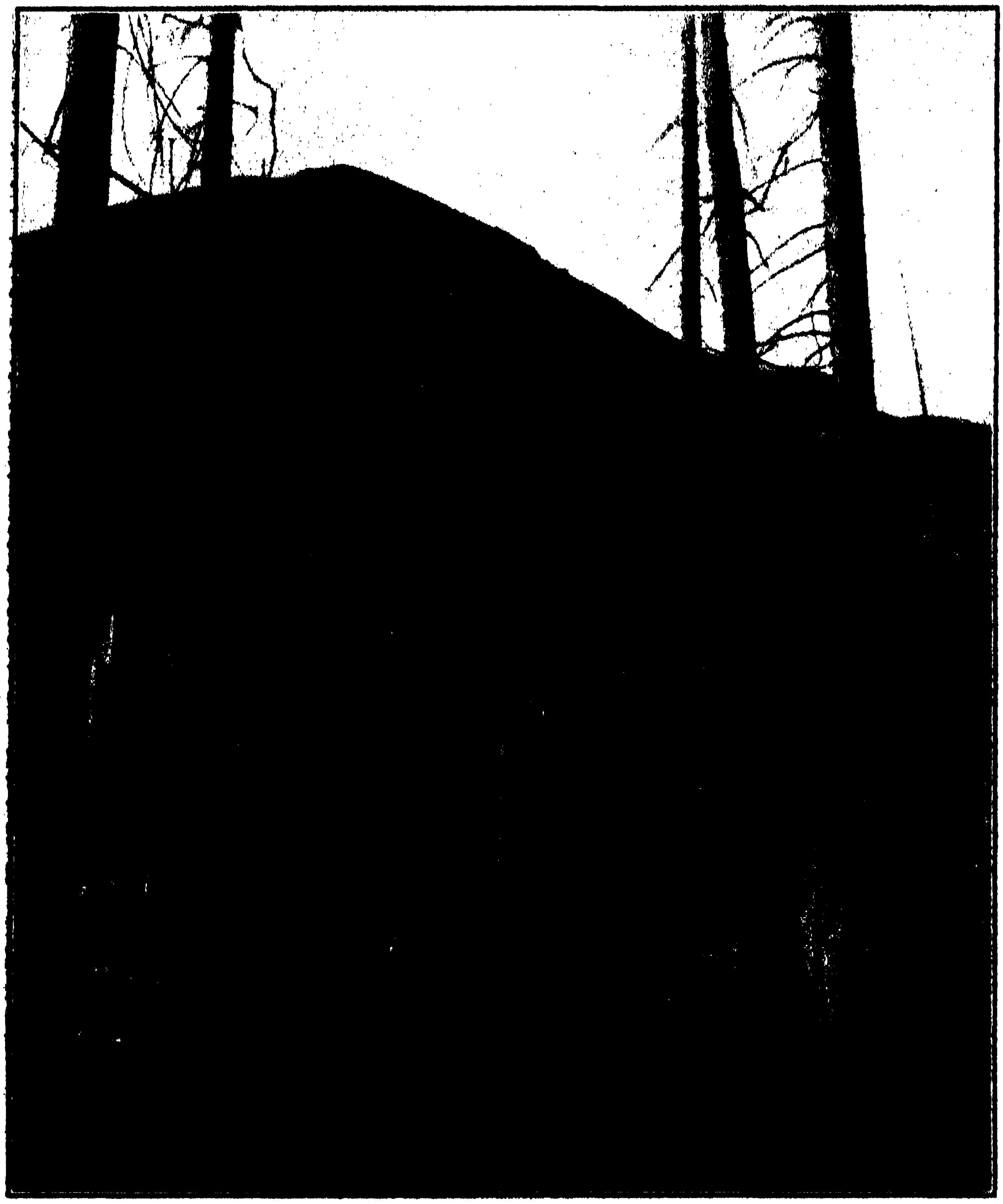
A few miles farther on Moose Creek Canyon opens out into a valley with broad flats where two or three bold settlers are clearing farms out of the wilderness. This pioneer home-building is fraught with much hardship and little profit, but it has its compensations. If income is small, wants also are few and much of the living is yielded by the fertile soil and the abounding fish and game.

Moose Creek joins the Selway River, coming down from the south. At the point of junction the gulches narrow again and both streams emerge to the union from rockbound gorges. The Selway is a beautiful stream. Our trail followed the bluffs along the right bank often high above the stream into whose green and transparent depths we loved to gaze. It was low water and the high water line plainly visible on the rock wall of the chasm was fully twenty feet above the surface of the stream in August. The absence of driftwood and light debris on the immediate banks of this stream bore testimony to the swift current of its high floods, and the immense volume of water which in season pours down this channel indicates the abundance of its sources, largely in melting snow.

Our objective for this day's march was Cedar Camp, about twenty miles from Maple Creek, but upon arrival it was apparent that very little feed could be had for the horses. We were now in the green forest, and at this point especially the deep shade was inviting, but no feed no stop, so we decided to push on until the horses could be taken care of. This took us about three miles farther to the mouth of Meeker Creek, where Mr. Hobbs called a halt with a rather dubious indication that feed might be had on the hills above us. Looking up we could see the bald brows of bluffs facing the south, where the soil, too dry for a forest, bore a scant growth of bunch grasses. It was thought that this probably extended back far enough to afford fair pasture for the animals. Accordingly they were turned out upon the slopes and a barricade erected to keep them from coming down.

This was our eighth day out. We had hoped to continue down the river at least as far as the falls some twenty miles below, but the scarcity of feed made it seem best to turn toward the head of the Selway, which meant retracing our steps as far as the mouth of Moose Creek, where we would turn south up the valley. We were in some doubt as to where our course could profitably be laid and one of our difficulties was in securing adequate information as to trails and feed. Our maps were the best to be had, but they were either incomplete or old and indicated nothing as to the conditions of the trails, which in some cases were found to have been abandoned for years. Oral inquiry was not much better in eliciting dependable information.

At Meeker Creek the altitude is about 2,200 feet. The dryness apparent on the higher exposed slopes indicated our entrance into a different climatic zone, the Arid Transition, which we left at Hamilton, Montana, at 3,600 feet and which prevails generally in the intermountain valleys farther east from 4,000 feet down. Along the Selway at this



FIRE DESOLATION AT MAPLE CREEK

DEAD TREES IN THE FOREGROUND ARE ARBOR VITAE (*Thuja plicata*).

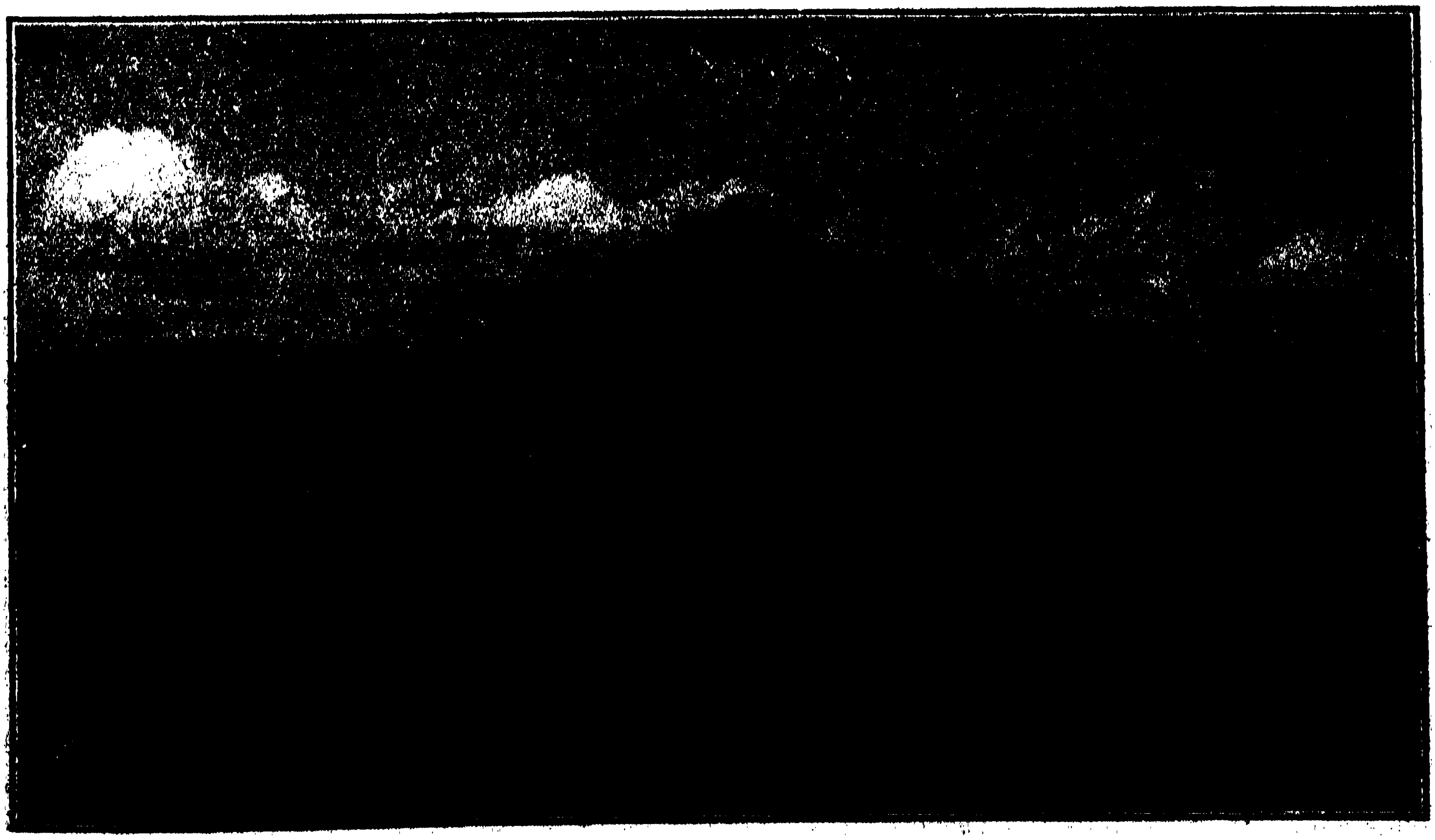
point and in sheltered canyons and on north slopes we found ourselves in company with the grand fir and other plants suggestive of Humid Transition of the Pacific Coast, conditions indicative of greater rainfall and higher relative humidity than obtains east of the Bitter Root Range.

At Meeker Creek our fortunes began to change. Up to this point our trip was pleasant and successful, but the subsequent days were not soon to be forgotten. Dawn had not broken on this camp before the wakeful ear of Dan caught the sound of bells descending the hill. The horses had passed the barricade and were making for the river trail. They must be turned back! Hurriedly rolling out of his blankets and slipping on his shoes he rushed out in his night clothes to reach the point on the trail some distance below the camp, where they seemed to be coming down. Whether the perversity of the beasts or fright at his appearance stampeded them we will never know, but they succeeded in plunging into the main trail and headed up the river on the run. The trail along the Selway for miles is cut out of the side of the bluffs often precipitous above and below with no chance for detour. There was nothing to do but to follow the animals and trust to an almost impossible chance to get beyond them. Seven miles lay between camp and the mouth of Moose Creek. Here the trail forked and the branch to the right leading up the river crossed a bridge over Moose Creek. At the farther end of this bridge a gate barred the way. Here at last luck favored Dan. The horse is often a stupid animal, and in this case they entered the *cul de sac* and were captured. Returning to camp by eight o'clock Dan refreshed himself by a plunge in the river, and the incident of the horses was dismissed as part of the day's work.

The outfit was soon got in motion and by eleven o'clock we were back at the forks of the trail, passed the bridge and the gate and began the ascent of the Selway Canyon. The Moose Creek Ranger Station was reached about noon. Our coffee had been lost earlier in the trip and we sought here to replenish this article but were refused. The ranger was absent and the youth in charge resisted both our money and our prayers, so we went on our way.

Here also for miles the trail wound in and out around the high bluffs above the stream. The day was hot and the trail being on the slopes facing the west we got the full force of the afternoon sun. None of us felt much enthusiasm, what with the difficulties of the day and the uncertainties as to what lay ahead. Early in the afternoon two of the party, Dan and Edward, showed marked symptoms of illness, and at last we were glad to pull off the trail and make camp at Dog Creek, seven miles above the forks.

We had hardly dismounted when the younger boy fell in a faint. Dan retained consciousness but retired to a hastily



GRAVE PEAK

WITH LOOKOUT STATION ON SUMMIT. ALTITUDE 8,200 FEET. FOREST A MIXTURE OF SUBALPINE FIR (*Abies lasiocarpa*), WHITEBARK PINE (*Pinus albicaulis*) AND LYALL'S LARCH (*Larix Lyallii*).

made bed. Here we were in the heart of the Clearwater wilderness, nearly fifty miles from the nearest wagon road which lay beyond the high Bitter Root Range, and two cases of the dread spotted fever on hand, that swift disease that usually carries off its victims in a few days. For a day or two the boys had been somewhat indisposed but had not given the matter serious consideration. It was now the ninth day after entering Blodgett Canyon, one of the worst localities of spotted fever infection, but at this season generally considered safe. The wood tick (*Dermacentor venustus*), which in the opinion of physicians is generally accredited with the transmission of the disease, is active in the earlier part of the season, but in midsummer passes into a dormant stage. On this trip we saw but one tick and that was not on either of the boys taken ill.

The writer will spare the account of the harrowing days that followed—of our helplessness against the progress of the disease, of the forced march across the Bitter Roots by the shortest route which followed an abandoned trail full of fallen timber, of the anxiety and strain, and of the final passing of brave Dan. We might better dwell on the quiet heroism of Ned Hobbs, on the fine loyalty of Severy, and on the staunch service of a few forest workers who aided us in our extremity. But space here will not permit of the account which may sometime be told more in full.

In the afternoon of the sixteenth day of our trip we reached the foot of Como Lake at the eastern base of the Bitter Root Mountains. Here we made camp. A rough, winding, wagon road comes up from Darby on the Bitter Root River. A message having been sent to Missoula, it was evening when the hum of a motor was heard and the family auto appeared. We now bade farewell to the camp, to the stalwart foresters who had assisted as stretcher bearers, to our good friends, the Hobbses, whose courage and hard work had meant much to us, and turned our backs on those scenes and experiences which we can never forget, but which linger like the impressions of a bad dream. The car rolled down the steep grade to the highway and opened up on the seventy-mile run to Missoula. The dark road was deserted, valley towns one by one were left behind, until we pulled up at home and the Selway trip was over.

The coming of the fever put an end to this botanical enterprise. While systematic record and collections were not made on the return trip the scenes through which we passed remain in the writer's mind strangely as vivid as photographs. The winding trail and its obstructions, the bends and pools and cataracts of the streams, the mountain lakes fringed with fir and spruce, Rock Creek Pass and the towering peak of El Capitan, the camp sites and the serious company, the vegetation and what not. Some old lodgepole affording the finest specimens of the species *Pinus contorta*, ever seen, fine patches of *Aster* and *Solidago* in the mountain meadows, these and others remain still indelibly printed on the memory. On the whole the cross-section of the vegetation represented by the Rock Creek Pass over the Bitter Roots differs little from that of the Blodgett Pass, twenty miles farther north, except perhaps as affected by slightly drier conditions and the thinning out or the absence of certain forms which appear proportional to the increasing humidity with the progress northward.

With this, the somewhat meager account of the Selway excursion, this paper will close. The following season the writer with another outfit crossed the Bitter Roots farther north and examined the vegetation around the sources of the Lochsa and the upper Clearwater. The story of this trip will appear under the title of the Lolo Trail.

WHO INVENTED IT?

By S. C. GILFILLAN
EDGEWATER, N. J.

"BLESSINGS on the man who invented sleep," said the classic Sancho Panza; and the English balladist:

> So I wish in heaven his soul may dwell
> Who first found out the leather bottell.

Perhaps, indeed, he was thinking more of the inner spirit of the bottle, than of its outer integument. Anyway these old-timers express a thought that is common to-day, the rule even, and which not even a single social scientist has shaken himself sufficiently free from, *viz.*, that the great inventions were made by certain great men. We know the names reported for many of the inventors, chiefly Americans, which were taught us in unquestioning youth. Many heroes have been forgot, perhaps, but they were individuals, it is believed, and might be known. Here is Rear-Admiral Bradley A. Fiske, U. S. N., for example, a very distinguished inventor, author of "Invention, the Master-key to Progress" (1921), saying in it that to Dædalus are ascribed the saw, gimlet, plumb-line, ax, wedge, lever, masts and sails. "As no records show to us that the inventions just enumerated (except masts and sails) had been invented elsewhere, we may feel justified in inferring that they were invented in Greece by Dædalus, or by some other man bearing a different name—or by some other men." Not one was. In some of his other passages, to be sure, the Admiral reflects a sounder sense of inventive history.

However, that all inventions were made by certain men, and the great inventions by great men, is the almost universal belief. But here a difficulty at once appears. The famous inventors are called great because such and such an invention is attributed to them. Yet we do not call a commander a great general for gaining one crucial battle, nor a poet great for one perfect poem. For a single achievement, however momentous to us, may have been an accident to its maker.

Now among all the inventors of whom popular history tells, only three, Archimedes, Ericsson and Edison, have been credited with more than one important invention. Others may have equaled them in genius, but not in luck. So leaving aside these three "great inventors," let us take up the "inventors" who did everything else, and later the question of who were really great inventors.

Who invented the telegraph? Any American who has been through the eighth grade knows that it was Morse and Vail, in 1844. But there was an English commercial line seven years earlier, and the Germans credit the telegraph to Sömmering, of Münich, in 1809, and in Switzerland there was an electric telegraph in 1774, and one was proposed in Scotland in 1753. The matter becomes rather confusing for the eighth grade. Who invented the friction match? There are so many claimants that we don't know who the devil invented it, and so have named it after Lucifer. Who devised the aneroid barometer? In Paris in 1848 two men, Vidi and Bourdon, each claimed it, with apparent sincerity, and different courts decided for each of them. But 152 years earlier the philosopher Leibniz had suggested such a barometer, describing it exactly. If we should really examine the roll of honors, from Archimedes, called the inventor of the pulley, to Marconi and the much overrated Wright brothers, we should find that almost every claim is disputed, and rightly.

The chief reason for this confusion of parentage is that the process of making a great invention is totally different from the common understanding about it. A great invention is not a completed product, issuing at one time from the brain of one inventor. It is a multitudinous collection of little inventions, and is a growth of centuries. Had a single inventor to make the whole, he would need more hands than a monkey, more lives than a cat and more inventive genius than Pallas, Hermes and Loki combined. Let us illustrate this by the history of the steamship.

The first stage of an invention is the beginning of a desire for it. We find the utility of the steamship perceived by Homer, who sang of the marvelous, great, black ships of the Phæacians, which without sail or oar or crew, sped swiftly to the remotest ends of earth, bringing back merchandise. Next, paddle-wheels descend from Roman days. In the thirteenth century Roger Bacon, from his experiments with gunpowder, glimpsed the internal combustion engine, and the means of fulfilling the Homeric desire. He wrote "Art can construct instruments of navigation such that the largest vessels, governed by a single man, will traverse rivers and seas more rapidly than if they were filled with oarsmen." A steamboat had probably been suggested by 1651, and built by 1738, and we have patents with descriptions of 1729 and 1736. But no success was to be expected from such craft, for their engines were wretched. Watt's double-acting expansive steam engine appeared in 1782, and the next year the Marquis de Jouffroy had built a great boat, not fast enough, at Lyons. Before the end of the century steamboats had been built by many inventors, especially Rumsey on the Potomac and Thames, Fitch in the Delaware, who realized good speed and long commercial use, and by Evans, and Miller, who in 1789 made 6 knots on the Forth & Clyde Canal. In 1802 on the same water Symington's *Charlotte Dundas* was a perfect success, save that she washed down the canal's banks. Presently John Stevens, of Hoboken, had speedy steam yachts on the Hudson, even with twin screws, tubular boilers and high pressure, excellent save for the damning workmanship in their motive plant.

Meanwhile Fulton, as we know from direct testimony, had been studying the plans or boats, and interviewing the designers, of every one of the important previous projects, in France, England and America. So had the other inventors been studying, the steamboat evolving out of joint experience; but none were so assiduous as Fulton. In all about thirty steamboats had been built, all in those three countries, generally in the order given. Fulton first built a 66-foot boat on the Seine at Paris, and obtained some speed, but little attention and no success. So he returned to the great rivers of America, and in 1807 launched the *Clermont* in the Hudson, and steamed for Albany at 5 miles per hour.

There was apparently nothing new and valuable about this famous boat. Her engines were from Boulton & Watt, and in no way except in her proportions she was superior to or different from her predecessors. Why then was she more successful? Chiefly because Fulton had, with his forerunner Stevens, made one crucial discovery—the Hudson River—and got a patent on it! It was fitting that we celebrated together the anniversaries of Henry Hudson and Robert Fulton, for each owes his greatest fame to discovering the Hudson River, although each had been preceded by a navigator of its lower waters, and had pioneered more elsewhere. This river was the one best water in the world on which to run a steamboat. It was the *only* water which combined all the advantages of poor winds (for good winds would mean superior efficiency for sailing vessels), no tow-paths, bad roads, trifling waves, a deep channel, no rapids, a long straight route between centers of commerce, yet paralleled only by bad roads, with an intelligent population, no national boundary, and an abundant fuel supply. I am convinced that the lack of success of several pre-*Clermont* steamboats was mainly due to their faulty environment (and also inferior patent protection). The Hudson was the one proper water for such craft as they; and it is noteworthy that the Hudson has always continued to float the best river steamboats in the world. But a New York paper on the famous day said that Fulton's boat had been invented with a view to navigation of the windless Mississippi—Fitch's aim, which was attained before there was a successful boat in Europe.

I do not mean to disparage Fulton's genius: he was a most brilliant inventor of many other things; but he did not invent the steamboat in the *Clermont*. Nor did he later, for, after rebuilding her at once and ably adapting steam to various types of vessels, and striving to monopolize steam navigation in New York waters (like his successors in accidental fame, the Wright brothers), he died in 1815.

The reader has not been fatigued, we hope, by the voyage of the steamship from Homer to Fulton, for this is only the beginning of her trip, and we can best understand inventions in general by keeping full speed ahead. The *Clermont* was a crazy craft, unseaworthy, and slow as a geologic process. If steamboats had stopped evolving with her they would be as rare and unimportant to-day as dirigible balloons or intelligence in a jury. She is like the ape in our ancestral tree, which we left long ago, and glad we are to have left it. But this was her significance—once it was possible to make money out of steamboats, more and more craft were built, and each brought its little mite, or its valuable contribution, to the art of steam navigation. Each added its inventions, its improvements of detail, which enabled the steamboat to navigate more waters, to be swifter, safer, larger and more economical and effective in every way. So the number of launchings and the rate of progress steadily grew.

About the time of the *Clermont*, Stevens had reverted to low pressure and paddle-wheels, and produced a small vessel of high speed. His *Phoenix*, launched a little later, which first of steamers sailed the sea, and survived a storm, in 1809, when driven by Fulton's patent to the Delaware, was a better ship than the *Clermont*, with a simpler steeple engine and much better lines. She presents excellent evidence of Fulton's non-necessity, for it appears that she was designed chiefly previously and independently, beginning in 1805, and that there was likely as much give as take with Stevens.[1] Thus we may not conjecture, but flatly state, that had Fulton never lived, the first fully successful steamboat would have been launched by the Stevenses at practically the same time and quite the same waters as the *Clermont*.

The ripening art spread slowly, and where most needed. The St. Lawrence knew steam in 1809, and the wild but swift and windless Father of Waters in 1811. Not until the year after that was a steamboat successful on a river of Europe (the Clyde). By 1819 they smote the sea with the resounding paddle, for short coasting jumps. Not until 1840 could they cross the broad Atlantic, with its wind and waves, as efficiently as the sailing packets, and then only for cabin passengers. By 1893 half the world's marine tonnage was steam-propelled, but not yet has the steamship become so perfected as to be better on all voyages than the sailer (also constantly perfected).

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[1] Authorities have disagreed as to the date of the *Phoenix'* launch, but it was April 9, 1808, while her independent design is likewise attested by A. D. Turnbull, Stevens' forthcoming biographer.

A steamship like the *Leviathan* resembles the *Clermont* no more than she does the Flying Dutchman or a quinquireme. Perhaps every principle that was in the *Clermont* is tucked somewhere aboard the modern marine monster, but her 60,000 tons are built up on inventions other and countless, millions of inventions. She has ears beneath the water, wherewith to hear the signals of the sea, when the fog lies over, and she has varied instruments as well to pierce the fog, hearing and making heard. The stockless anchor in her bow is an invention; and so are the machines that forged the mighty links of her chain cables. There are typewriters in her office, and elevators connect her decks. The anti-fouling paint on her keel is an invention, and the tools that made it. Cheap steel, such as makes possible her hull, has been called the greatest of modern inventions; and necessary for that steel were all the instruments, processes and sciences involved, from finding the iron's ore in Lorraine, to devising the giant's thumb and finger, that pinched her plates together with one-inch rivets, and left the surface smooth. Her turbine engines, propellers, endless electrification—these are new. So we might progress from her keel up to the wireless antenna, and find represented in her, or involved ashore, so many inventions that their very descriptions would load the ship. Scarce one of them is indispensable for a great liner, yet all help, and all the millions of them are necessary to make her as she is. Few of these inventions were represented in the *Clermont*. The *Leviathan's* real inventors were half of all the fathers of devices or improvements who have lived since time began. She is a museum of modern civilization, riveted together and called a steamship. Fulton no more invented her than he did the moon. And just so is it with a printing plant, a telephone system or any other so-called great invention—each is the complicated product of a vast and age-old series of inventions in its own and all related fields, due to no one man, nor nation, nor century nor millennium even. An "invention" is simply a certain grouping, defined by an English word, of all the achievements of men's minds since time began. So the "great inventions" were never made by any one—each is perpetually being made.

Why then is there that ridiculous common report, echoed even by inventors and engineers, that Fulton invented the steamship of to-day, or any steamboat? It is a matter of language, and of psychology. People want a definite origin for things. "Jubal: he was the father of all such as handle the harp and organ. And . . . Tubal-cain, an instructor of every artificer in brass and iron." The Greeks gave their thanks to Apollo for the invention of the lyre, if not to Hermes, to whom also they ascribed the alphabet, astronomy, numbers, weights and measures, the syrinx, music, gymnastics, tactics and olive culture. But let us consult a modern authority, the Century Book of Facts (*sic*), "authentic, comprehensive, up-to-date," and published in 1902 in Springfield, Mass., according to the title page, under the editorship of Henry W. Ruoff, M.A., D.C.L. and sometime professor. We read here, along with a typical chronology of modern inventions, that wine was brought from India by Bacchus, weights and measures invented by Phidon in the year 864 B. C., and that the reported inventions of Dædalus, which Admiral Fiske cited, were made in 1240 B. C. What admirable precision! And see Professor Ruoff's cosmopolitan responsiveness to the voice of authority: Wheat bread was invented by Ching-Noung, 1998 B. C.; the flute and musical concord by Hyagnis, 1506; "it is, however, agreed that music was first reduced to rules by Jubal, 1800 B. C. "Silk was invented by Se-ling, wife of the Emperor Hoangti, about 2637 B. C. (never mind if authentic Chinese history does begin two millenniums later), and the violin in 5000 B. C. by Ravana, king of Ceylon. But as to weaving the compiler finds some difficulty, for the Egyptians ascribed the art to Isis, the Greeks to Pallas, and the Peruvians to the wife of Manco Capac.

A similar list, with mythology as bad, is to be found in *Le Machinisme Universel,* written in 1925 by Etienne Pacoret, "Ingénieur, Lauréat de sociétés savantes et industrielles," author of seven books on engineering, perfectly competent in the engineering side of this his latest, but innocent of sociology, like the Admiral.

Now simply add an American myth that the steamboat was invented by Fulton. Primitive minds having their similarities, whether in Homeric Greece or Chicago, the recurrent question of whence something came, which it is known did not always exist, is answered by ascribing it to some definite and personal origin. "The telegraph?" Tom says, "why, some one must have invented it—it seems to me I've heard about Morse—yes, it must have been invented by Morse." Not just as a joke, but as an attempt at truer library classification in the Dewey system, I would suggest that grammar school American histories be classified under 292, Mythology, for this and similar reasons.

The fundamentalist assault upon biologic evolution is partly an expression of this same trait of the ordinary mind, which can not so easily conceive and remember the development of a gradual evolution, as a single creation by act of one person.

The popular idea, then, of an invention is a mythologic concept, a personal symbol to account for the origin of something. What determines the personage —why is Fulton called the inventor of the steamship instead of Roger Bacon or Symington or Thornycroft? That man is preferred as the titular inventor who belongs to our own national history, if possible, or to a related country, and who was the first man to make the device a commercial success. Fulton was no more the first man to improve the steamboat than he was the last, but he was the first to make money out of it. He is not deified just because he made money, but because his *Clermont* (with Stevens's *Phoenix*) was indeed a cardinal event in the evolution of the steamship. Previously, building steamboats had seemed a pretty sure way to lose money, so only a few fools built them. After the *Clermont* Fulton had money and reputation whereby to make further experiments, and other men, especially the brilliant R. L. Stevens, were encouraged to build boats elsewhere, to make money. The more boats were built, the more inventions were made thereon, and the faster the steamship evolved. What Fulton achieved, through his lucky step of launching the right sized boat on the right waters, was only to change the steamboat from say 95 per cent. worth while (*i.e.*, from a means of losing money) to 105 per cent. worth while (*i.e.*, a means of gaining money). There is a supremely important economic difference between a 5 per cent. deficit and a 5 per cent. profit—between the number of people who will enter a losing business, and a lucrative one. Yet the genius required to make that small increase of return was no greater than some later inventor's who raised the steampship's usefulness from 8,030 per cent. to 8,040 per cent. We shall speak in another article of the crucial importance of some one's being able to make money out of a contrivance.

Well, so it is with the mythology of each other invention—the Wright Bros. for the airplane, Bell to answer the telephone, Marconi for wireless, are selected out of the millions of their helpers, for having been the men who were conducting an invention, the gradual product of centuries, in that moment when it crossed the dividing line between commercial failure and commercial profit.

We have mentioned the tendency for the titular inventor to hail from the right country. The English believe that the steamboat was invented by Symington, the Scotch call Bell (1812) the father of the steamboat, the French swear by Jouffroy, and the Spaniards have had a thoroughly mythical Blasco de Garay. Mythology does not relish heroes who were foreigners. The American list of inventors allots most of the honors to Americans, and about all the rest to Englishmen (including Marconi who did his work in England). Perhaps these personal symbols, as parts of our national epic, our patriotic religion, are necessary or proper concepts for grammar school children. At any rate they are bound to be propagated while Americanization is the watchword, for they strengthen hero-worship and patriotism, combatting socialism. But at least let those who are old and sane enough to hear such truths about the great inventions as are known to any specialist, not repeat that parrot folly of assigning single personal symbols to the great inventions, on which millions of minds have toiled for centuries, and still toil. There is no more necessity for our believing in such an origin for the sewing-machine than there is for such an origin of man or coats or modern agriculture; and to continue doing so would be equally fatal to all understanding of inventions.

If we desire great inventors to look up to, for learning how to live and labor, let us reverence those discoverers in all lands who through a lifetime of successful inventing showed indomitable perseverance, egregious ingenuity, shining genius. Such heroes include (remembering their lives, not their mythologic attributes), Archimedes, Roger Bacon, the Marquis of Worcester, Watt, Fulton, the Brunels, the Stevenses and Stephensons, Ericsson, Edison, Siemens, Hiram Maxim, Elihu Thomson, Charles Scribner, Steinmetz, Emmet, Coolidge and others who have labored long, avidly and brilliantly to advance human life.

But the common idea that the great inventions have been dependent upon the genius of a single man, so that if the great So-and-so had died of whooping-cough all history would have been different—this idea must now appear erroneous; and it will appear absurd from our further examination into the social process and controls of invention.

BACK TO METHUSELAH?

By PAUL POPENOE
PASADENA, CALIFORNIA

THAT the fountain of youth is just around the corner is one of the most widely heralded of recent discoveries. Man is assured that, thanks to modern medical science, his life is to be immensely prolonged in the near future. Newspaper editorial writers vaguely quote Irving Fisher and Julian Huxley, while they ask whether their subscribers are really ready to use wisely the additional decades that are about to be thrust upon them.

Making the promise more specific, a speaker tells the twentieth annual meeting of the American Sociological Society "that in the year 2,000 A. D., unless we wreck our civilization before that date, many a baby will be born with 200 years or more of life before it; and that men and women 100 years of age will be quite the normal thing, but instead of being wrinkled and crippled they will still be in their vigorous prime."

Such a result would amount to an unprecedented acceleration of evolution; for longevity is an adaptation that fits each species to its conditions of life, removing the adults at a certain time after they have had an opportunity to reproduce.

There has been a gradual evolution in the length of the pre-reproductive period, since the year 1. A bacterium is ready to reproduce after forty minutes of life, a Ph.D. perhaps not until after forty years. During the course of hundreds of millions of years, the general tendency has been, as C. B. Davenport lately pointed out, toward the establishment in mankind of a relatively short uterine period, long childhood, short reproductive period, and long post-reproductive period. But there has apparently not been any very widespread and striking change in any of these respects in historic times, though there have been marked and deleterious changes in them in limited parts of the human race, namely, the most highly educated strata of the most highly civilized nations.

Two or three thousand years ago it appears from the studies of Karl Pearson and W. R. Macdonnell that the expectation of life at birth was ten or twenty years less than at present. At the higher ages, however—say, after sixty—the ancient Roman's expectation of life was probably higher than is that of the American to-day. This was due to the higher selective death-rate in early life, which weeded out the weakest and left only the strongest to survive. The same factor (and not, as Elie Metchnikoff supposed, the drinking of buttermilk) may produce an unusual proportion of centenarians in a rough country like Bulgaria.

Most of the progress of the medical sciences has certainly been within the last two thousand years. It appears that it has not increased the expectation of life at birth more than 100 per cent. at the most; and that long-lived people actually may not, on the average, live as long as they used to. Hence the suggestion that the average span of life may, in the next two or three generations, be increased some 300 per cent. or 400 per cent., involves an unheard-of speeding up of evolution.

Evolution is not a sprint, but an endurance contest. Such bursts of speed have sometimes not been very successful in attaining their goal. One of the outstanding and familiar examples is that of the aborigines of the western hemisphere who, after the arrival of Columbus, tried to cover in a few generations the ground that Europeans had covered in an equal number of millennia, in respect to resistance to certain zymotic diseases and to alcohol. The effort killed nearly all of them. In some localities, as, for instance, Tasmania, there is literally not a single member of the old native race left.

The practicability of such accelerated progress in the case of longevity is urged by Hornell Hart, on the ground that it can already be demonstrated in other aspects of man's power to control his environment. He cites the development of edged tools, transportation, methods of warfare, and the like. But these are social accomplishments, not phases of organic evolution. Indeed, the distinction between inheritance and tradition is precisely that in the latter each generation begins where the preceding one stopped; in the former, each generation begins very nearly where the preceding one began.

And human longevity is very definitely an organic, not a cultural, attribute.

As to the exact mechanism by which mankind is to be enabled to take this running broad jump in its evolution, all the evangelists are a bit vague. They merely point to the lengthening of the average span of life, and by projecting this forward can easily, if they desire, prove that the span asymptotes infinity.

When the facts are examined in more detail, it appears that much of this increase in the average duration of life is, in one sense, merely statistical, resulting from a decrease in infant mortality. If a population is made up of one thousand people who died before the age of one, and one thousand others who became centenarians, it is evident that the average duration of life is some fifty years. If the infant mortality is eliminated, the average duration of life is immediately doubled, though the oldest do not live a day longer than they did under the first hypothesis.

The much vaunted increase in the span of life is therefore partly a reincarnation of one of the commonest statistical bugbears, namely, the misinterpretation of the arithmetical mean.

While the infant mortality has been somewhat decreased in most civilized countries during the last generation or two, the actual gain is by no means as great as it is often represented to be. Part of it is a mere bookkeeping gain, due to the better registration of infant births. The usual measure of infant mortality is a fraction, which consists essentially of the ratio of deaths to births. Deaths, which involve an undertaker and a cemetery, therefore some publicity, have always been registered much more fully than births, which commonly occur in the privacy of the home. Even now there is probably no area in the United States which registers as large a percentage of its births as it does of its deaths. But a vigorous campaign by the Census Bureau and many other agencies has resulted in a steady increase in the efficiency of birth registration. This steadily augments the denominator of the fraction, without changing the numerator, and results in an apparent, though spurious, decrease in the infant mortality rate, even if the proportion in fact does not change.

This is frankly recognized by many public health authorities. Thus the California State Board of Health Weekly Bulletin, November 27, 1926, after mentioning the remarkably low infant mortality rates in some cities of the state, continues:

> In some California cities, however, the high infant mortality rates are most deplorable. It would seem that there is little or no community pride in making an effort to salvage these human lives. Undoubtedly the most important factor in the reduction of infant mortality lies in securing thorough registration of all births. This is obvious when it is considered that the infant mortality rate is the proportion of deaths of infants to the total number of live births. If all births are *not* registered, but if all deaths are registered, the infant mortality rate will of course be correspondingly high. The more thoroughly that births are reported in any community the lower its infant mortality rate will be. Next in importance in the production of a low infant mortality rate is the provision of pure milk supplies, etc.

There has doubtless been some real decline in the proportion of deaths under one year, but this is largely counterbalanced by a corresponding increase in deaths between two and five years—an offset on which the infant welfare agencies do not have much to say. Inasmuch as more than one half of *all* deaths are selective, representing the elimination of the least fit, it would be expected that pulling weak babies through the first year would result merely in saving that many more to die in succeeding years—for by inheritance they are not destined to prolonged survival. The studies of Karl Pearson, E. C. Snow, F. S. Crum, Arne Fisher and others leave scarcely a doubt that this is what happens. A decline in the real infant mortality rate is always largely offset by a rise in the child mortality rate.

The changes in the adult death-rates are also equivocal. Speaking broadly, it may be said that the tendency in recent decades has been toward a decline in adult deaths due to infectious diseases and an increase in adult deaths due to degenerative diseases. Both these trends seem to be continuing. The increase in the death-rate from diabetes has been much greater than any other.

To bring about a decline in the death-rate from infectious diseases is, theoretically, not very difficult. It involves such theoretically simple measures as the extermination of a certain species of mosquito, or the destruction within the human body of a certain type of micro-organism. A continued gain in the war against such diseases might be expected for a long time to come although the evidence in the case of tuberculosis, which has been combated more vigorously than perhaps any other in the last half century, is not altogether reassuring. In any case, a point must eventually be reached at which the gain will become small, or disappear.

The conquest of the degenerative diseases is theoretically more difficult, for it can not be brought about by any simple vaccination. It must be based largely on a change in the living habits of the race, and it is not so easy to get a middle-aged business man to stop eating and start exercising as it is to clear the hookworms out of his system and immunize him against diphtheria. Conditions appear to be getting worse rather than better, in respect to man's biological habits. While such palliatives as insulin may relieve his sufferings they are, from an evolutionary point of view, merely palliatives. If they change the constitutional make-up of the race, it is likely not to be for the better, since the result is the survival and possible reproduction of persons with weak resistance.

The constitutional make-up is changing in other ways, and it is undoubtedly changing for the worse.

Longevity is well known to be inherited; that is to say, a certain toughness of constitution is passed on from parent to offspring, which enables the survival of the individual even under relatively unfavorable circumstances. On the other hand, even the most favorable surroundings do not insure survival unless one has the constitution. This was well shown by A. Ploetz's study of length of life among the royal and noble families of Europe, where children have at least never lacked for food and medical attention. There was a regular and close association between the parent's length of life and the death-rate of his offspring.

The gradual increase in length of life, in the course of evolution, has presumably been due, at least partly, to the fact that those who lived the longest (thereby showing their possession of unusually good constitutions) also left the largest number of children to inherit and pass on these good constitutions. Karl Pearson first called attention to the correlation between fertility and longevity, which has since been corroborated by Alexander Graham Bell and others.

The "small family system" has knocked the spokes out of this wheel of evolutionary progress. However great the benefits arising from voluntary parenthood, it has often been pointed out that one racial effect is, under present conditions, disastrous. To diagram the problem, suppose that under the old dispensation a vigorous, long-lived couple had ten children, while a couple coming from defective stock, inheriting weak constitutions, and dying young, had only one. This is not so very far from what actually happened in many cases. Evidently people of sound stock would outnumber people of weak stock ten to one in the succeeding generation; and the race thus evolved toward increased longevity.

But under the present system, which tends to limit every family, no matter how sound the stock, when the priestesses of birth control warn all intelligent people against "breeding like rabbits," while economic and educational conditions make it easier not to breed at all, the situation is changed. The hypothetical weak couple probably still produces its one child; the strong couple produces not ten children, but perhaps two. Thus the strong outnumber the weak in the next generation, not ten to one, but only two to one; and the tendency is for the advantage of the strong to decrease steadily.

In other words, the widespread and severe limitation of births in the better educated and economically successful part of the population results inevitably in a decrease, in each generation, of the average fitness of human constitution. It is against this handicap that medical science must work, in attempting to prolong life. While it gains new technical tools in each generation, it at the same time finds poorer material to work on. The proportion of people in the population with good constitutions becomes progressively smaller; at the same time the habits of life, which need the best of constitutions to withstand, constantly become more unfavorable as the progress of so-called civilization takes mankind farther and farther away from the environment to which it is, biologically, still adapted.

Simultaneously, the germinal constitution of the race seems to be deteriorating through the multiplication of sublethal genetic mutations. Experimental breeding indicates that such mutations are occurring continually, though in small numbers, in any stock. Most of them are recessive, and in a state of nature they are probably eliminated almost as fast as they arise, through close inbreeding and stringent natural selection.

In the human species, close inbreeding is almost a thing of the past, and the intensity of natural selection is somewhat lessened. It is therefore impossible to prevent the dissemination of these injurious mutations. They make the race weaker in each generation, and apparently must continue to do so, for there is no prospect at present that medical science can ever succeed in touching them.

Analyzed thus even superficially, the problem of longevity is so involved that it appears to me scarcely to justify the optimism that is sometimes generated very easily in public health meetings.

From the clinical point of view, much can be done in individual cases to prolong life. It is this point of view that seems to have been adopted by nearly all who have written on the subject lately.

From the evolutionary point of view, the picture is not so simple. When the clinician's success is in the field of infant mortality, it tends partly to counteract itself by a subsequent increase in child mortality; and also to increase the average weakness of constitution of the adult population. This weakness is at the same time being increased in several other ways. Sooner than is anticipated, the race may reach the position of equilibrium, when the continuing progress of science will find its counterpoise in the continuing decline of man's inherent fitness.

No matter how great one imagines the future progress of science to be, it is not likely altogether to abolish natural selection, any more than Einstein's revision of Newton's laws of gravitation enabled his pupils to lift themselves by their own bootstraps.

Until man becomes an angel, he will remain an animal and continue to reproduce organically. It is, then, still open to question whether the average span of life can be greatly and permanently increased by any agency except eugenics.

THE GRASSHOPPER PLAGUE OF 1866 IN KANSAS

By Dr. WILEY BRITTON

KANSAS CITY

FROM the earliest recorded time, communities of the human race have been afflicted by different kinds of plagues, in some instances wiping out large populations.

In the first chapter of "The Iliad" there is a description of a plague that afflicted the Grecian army when it was on the point of sailing for Troy to open the Trojan war.

> Nine days throughout the camp his arrows flew.

In that age of the world all plagues and disasters were charged to the leaders of the people disobeying some oracle, prophet or seer who claimed inspiration from the god of the nation and who was offended by the disobedience alleged.

In Biblical times there is also mentioned in several of the books of the Old Testament brief accounts of plagues, as "There died of the plague 24,000."—Numbers xxv, 9. There is also mentioned a plague of locusts in Egypt, which some writers have interpreted as the same kind of plague as our Kansas grasshoppers.

The Kansas plague of grasshoppers was attributed by the leaders of religious thought at that time to the anger of the Christian Deity who sent it as a punishment for the sins of the people. These same leaders of religious thought, the dominant thought and influence up to recent times, have attributed all other plagues and disasters to the anger or displeasure of their Deity, who sent them as punishments of the communities for their sins of omission or commission.

The priests or preachers of the time who claimed to be in touch with the Giver of all good things offered up prayers for the abatement of the plague of grasshoppers, but there was no abatement until the hoppers had destroyed every living green thing out of doors in a swath more than one hundred miles wide from the northwest to the southeast part of the state, and when they came to the western line of Missouri they commenced weakening and fell upon the earth, and scarcely a hopper passed the eastern line of any of the western counties of the state.

It is certain, and remarks were made at the time, that the people of western Missouri did not suffer any serious effects from the plague like the people of Kansas; yet no Kansan at that time would have admitted that Missourians were spiritually better than Kansans.

In the evolution of intelligence and a broader view of the universe and man's place in it, there is being developed a saner view of plagues and disasters of all kinds from floods, fires and accidents, and instead of charging them to an angry and offended Deity, men are turning more and more to science for explanations. Many things that were once held to be due to an inscrutable power are now considered due to natural causes. In the last sixty years there has been a wonderful change in the views of men in regard to their relations to the universe and to each other.

While we have good people among us who have not yet outgrown their anthropomorphic conceptions of the universe, many of them do not appear as certain of their positions as formerly.

Men of science have not only given satisfactory and rational explanations of the plagues and disasters which have not only from the dawn of history, but from pre-historic times, afflicted the human race, but they have in the most civilized countries for more than a generation been devising ways and means for fighting the agencies of these afflictions until the common man is beginning to depend more on their efforts for relief than on the prayers of the holy man.

Suppose that a farmer's hogs have been exposed to hog cholera; instead of going to his preacher to save them from the disease, he goes to the veterinarian and bacteriologist and secures a serum for their treatment; if his child has been bitten by a rabid dog, he goes to the hospital and asks for the Pasteur treatment to make it immune from the disease instead of folding his hands in prayer to await the result. We need not multiply instances of this kind; they are familiar to every one who stops to think of the changed situation.

Every species of animal, bird, insect or parasite has its enemies, and science in the hands of patient investigators is now using species that are enemies of species that are enemies of man to attack and destroy his enemies.

For four years there have been migratory hordes of grasshoppers from Argentina to Mexico, and wherever they have alighted destroyed everything edible in sight in an incredibly short time. And like the Kansas grasshopper plague of 1866, they come in such vast swarms, a seething living mass, that they dim the light of the sun for seconds at a time. But the problem of controlling their destructive visitations has not appeared too great for scientists to handle. They have found natural enemies of the grasshopper; they have found a parasitic fly, a swift flying fly, that overtakes the grasshoppers and deposits maggots on their backs, and the maggots at once begin eating into the bodies of the grasshoppers and promise to check their migrations.

This opens up an endless field of investigation for scientists to find parasites harmless to man, but deadly enemies to his enemies. In his war on the enemies of man in recent times large or small, the scientists have been uniformly successful, either destroying the enemies or rendering their attacks harmless.

So great has been the success of scientific men in controlling or stamping out enemy attacks from the minutest parasite to animal migrations that the average length of life of man in the civilized countries has almost doubled during the last century.

Almost from the beginning of the warfare of science against plagues and pests of human kind, there has been bitter antagonism of good and devout men against the efforts of scientists to control or destroy the agencies of affliction sent by the offended priest of Apollo or the Christian Deity.

We all know that in the early efforts of the followers of Dr. Jenner to stamp out smallpox by vaccination there was much opposition by those who believed it was flying in the face of Providence or a scheme to thwart the divine will. Indeed there has been decided opposition in some communities in recent years to vaccination against smallpox on account of religious scruples, many believing that it was sinful to oppose afflictions the Christian Deity was pleased to send.

The writer was living at Fort Scott, Kansas, during the grasshopper plague in September, 1866, and observed it every day while it lasted. We had notice of the appearance of the pests in northwestern Kansas several days before the advance arrived at Fort Scott, and were prepared for the sight which no one then living had witnessed before.

The first day the grasshoppers commenced arriving only a few were seen alighting and hopping about on the streets, but they increased in numbers for three or four days until the air was literally alive with them as far as the eyes could see, a seething, living mass that dimmed the light of the sun at intervals for seconds at a time. It was an impressive and interesting sight.

After a week or so their flight gradually decreased until the early days of October, when they were not noticed in flight, but the bare spaces of ground where they alighted were alive with them, and it was on these spaces where they deposited their eggs in countless thousands; in places they must have been two or three layers deep. In their nesting places on the ground they soon became inactive and dormant and paid little attention to anything near them, and were picked up in large numbers by birds and other natural enemies.

They were not noticeable in movements after the first freezing weather came, but in a short time after their arrival they had devoured all edible vegetation, as the gardens, wheat fields, green corn blades, and the foliage of the trees and shrubs. We had in our garden of about one hundred feet square some fine growing cabbage and they attacked them the first day, and by the evening of the second day they had stripped them, leaving only the bare stalks.

The farmers in that part of the state generally sowed their wheat in September and the hoppers attacked the plant as it came up, and not a field escaped destruction.

They deposited their eggs in the ground in such large numbers that there was fear that when spring came with warm weather and they hatched out they would destroy the growing crops of corn, wheat and oats and all growing vegetation.

The next spring, the latter part of May, the eggs commenced hatching, and in a few days they multiplied in countless numbers, hopping about everywhere but doing very little damage to gardens and vegetation and in the fields. This stage lasted until the early days of June, when they had developed wings and sufficient strength to enable them to fly, and it was asserted by many persons that on a given hour they were seized with a sudden impulse and rose *en masse* and flew away to the northwest, the direction from which the invasion had come the fall before. The writer does not vouch for the sudden impulse of the young hoppers, but he does know that their disappearance from that section was quite sudden, and that after their reported flight they were not further seen, to the great relief of everybody, for fear of the destruction of the growing crops was almost universally entertained by the people.

Whether they had an instinct that caused them to migrate *en masse* like the wild passenger pigeon from southern Missouri in the early eighties we are not prepared to say. As an evidence of their sudden disappearance, it may be stated that no complaints were heard from the farmers of any damage to the growing crops of corn, wheat and oats that season.

As to the origin of the migration in the latter part of the summer of 1866, it was the common report that it started far in the northwest in the foothills of the Rocky Mountains, and we heard almost daily of its progress southeast until they reached southeast Kansas where their flight practically ended.

Since that time the all-seeing eye of the Government, through its agricultural and health departments, has been on the lookout for all kinds of enemies of the farmer and of the people at large, and the moment one is reported, ascertain the facts and declare war on it, the Congress making adequate appropriations of money to carry on the war as vigorously as if the country were attacked by human foes. Experiment stations were afterward established in all the states and provided with laboratories with the latest technique for making investigations complete under the eyes of experts in any given field of threatened danger.

The latest appropriation made by the Congress of this kind is one of ten million dollars for fighting the corn borer, a European pest which has lately been introduced into this country and which was considered very difficult to attack effectively.

How different to-day is the spirit of the people in meeting the attacks of plagues, pests and disasters, in the home or on the farm, from what it was sixty years ago. It is interesting to one living now who witnessed the events of that time.

Very little effort was made up to that time by the agricultural department, by the state or general government to ascertain the cause and source of migration of the grasshoppers, information which was essential before any plan could be undertaken for the control or destruction of the pests.

As previously stated, the leaders of religious thought, then the dominating influence in dealing with all kinds of disasters, pests and plagues, the enemies of mankind, advised the offering up of prayers to the Giver of all good things, to stay the devastation everywhere visible, and of course the devastation was stayed when there was nothing further edible for the pests to destroy.

No one seems to have thought anything about plagues of any kind being proper subjects for scientific investigation, for at that time science had entered into very few fields of investigation along that line, vaccination against smallpox being the most prominent.

Many Christian ministers preached against science and claimed that it fostered skepticism and unbelief in the scriptures. Those who believed in the efficacy of prayer could claim victory of routing the evil one, for the cold winter had frozen the grasshoppers and the birds and other enemies devoured them so that they were no longer a menace to the community. While it was claimed that the plague was sent by an offended deity as a punishment for the sins of the people, no specific and flagrant sin was mentioned.

The only discordant view about the matter was that the people of Kansas were a little sore at the deity for singling them out for punishment, whereas the people of Missouri, notoriously hard-hearted and sinful, were permitted to escape punishment, for the moment the hoppers in their flight came to the western line of Missouri they commenced to weaken and fell upon the ground paralyzed, and scarcely any passed the eastern line of the western counties of the state.

Since the grasshopper plague of sixty years ago there has been a wonderful development of the scientific spirit among the leading nations of the civilized world, and the scientists have with one accord rejected the view that the migrations of these destructive pests and the breaking out of many parasitic diseases are tokens of the displeasure of the deity who sends them as punishments for the sins of the people, but they hold that these scourges have been due to natural causes and by the aid of science may be prevented or controlled.

The scientists of the present day not only reject the primitive ideas and explanations of the afflictions that have fallen upon large communities of our race in past ages, but they have undertaken to investigate their natural causes, and by careful and patient experimentation have worked out the life-histories of many destructive parasites and developed measures for their destruction or control.

We no longer fear outbreaks of yellow fever or of plagues like the black death plague of the fourteenth century that took a toll of more than fifty million lives of the countries of Europe and almost depopulated some of the large cities, and why? Because when a single case of yellow fever has been discovered our health departments get busy and commence to clean up and to destroy the mosquito *stegomyia fasciata* in its breeding places in the ponds, lagoons and stagnant waters near human habitations, thus preventing the spread of the disease.

If in a single case plague appears and the parasite is properly identified, we at once commence destroying the rats carrying the rat fleas whose bites of human beings inoculate them with bacillus pestis, the destructive parasite, thus preventing the outbreak of the plague. And so we might go on with an indefinite number of preventative and curative measures which have been worked out by scientists for the prevention and control of diseases that once afflicted large sections of our race without any rational effort being made for the prevention or control of the afflicting agencies.

Let us return for a moment to the consideration of migrations of flying insects, the feathered tribes and animals, large and small. We are all familiar with the seasonal migrations of fowl, as wild geese, brant and crane and of wild buffalo, due to climatic influences and in search of food.

The pressure of populations on food supplies and failing food supplies have probably always been a potent factor in migrations of insects and animals, including the human species, sometimes aided by climatic influences. Nor have there been very long intervals of time between some kind of migrations in some part of the world.

At the present time the attention of this country is focussed on the migration of mice in Kern County, California, and the destruction of grain and everything edible in the path of the millions upon millions of mice. From the latest available reports the migration of the mice has already cost the people of the invaded district more than half a million dollars, and it is impossible to estimate what it will cost before the plague has been brought under control. The state and United States authorities have taken a hand in waging war for the destruction of the mice, and the ways and means devised promise success. The deadly poison of strychnine laid about the alfalfa planted areas where the mice were feeding killed them by millions and seemed effective in exterminating them. Cats and other enemies of the mice, turned loose among them, fled from the vast horde without attempting their slaughter.

Field mice are not only incessant feeders on grain, root crops and vegetables and other products of the farm, but they are prolific breeders. It has been estimated that the increase from a pair of field mice, if all breed and live, is more than a million individuals in a year.

A mouse plague in parts of France has been so serious that the Pasteur Institute has been called upon for assistance to control it, and the institute has been experimenting with a disease that kills off the mice in three days. It is stated that grain should be soaked in a solution containing the bacilli which causes the disease. When the mice eat the grain they soon take the disease and rapidly transfer it to others. This is probably the most effective control of the plague that has been tried out, and may be extremely useful in fighting similar plagues in other parts of the world.

There seems to be an increasing tendency of men of science, when they find a parasite doing great damage to animal or vegetable life, to make every effort to find another parasite that is harmless to such life, to attack and destroy the injurious ones.

In their war on parasitic enemies of man the scientists have already accomplished much, but if they further succeed in using harmless parasites, harmless to the interests of man, to destroy deadly and injurious ones, they will have accomplished still greater wonders.

The mouse plague in California could not probably have been abated by the people of the invaded territory without assistance from the outside, the state and the United States, and they probably would have been obliged to abandon their homes had they not received such assistance.

We are coming more and more to realize the possibility, and even the probability, that national migrations of peoples of past ages were due to attacks on their food supplies by enemies in the form of insects, parasites or animals, like the mouse plague of California, which the people were unable to control.

Before the development of science as we know it, it must have been impossible for many peoples to have successfully met some of the plagues we have had to cope with in the memory of some of our oldest people, and famine or migration would seem to be the only course left to such afflicted peoples.

THE BOTANY OF MARCELLO MALPIGHI, DOCTOR OF MEDICINE

By Dr. FLORA MURRAY SCOTT

> FOR the mind of man is drawn to those things that are more difficult and more perfect, the things that minister to man's need, and are held in high esteem. The years pass on, and mind and body fail in strength. The way that has been trodden seems vain, and a new road to learning is sought. But the weariness of age laughs this to scorn. At the end of the day a few stray fragments of knowledge are left, tempest tossed and in wild disarray, and no man's work is perfected. To me, most learned colleagues, I confess that it has happened so. In the burning heat of youth, I plunged into the study of anatomy. Then as I was curious about certain particular things I turned to the study of the higher animals, intent on making these matters plain. But no light came. And I found that only by comparison with simpler forms could I make any headway. So I next tried the insect world, and this too had its difficulties. And last of all I came to plants, for I thought that if I mastered these, I might retrace my steps upwards to the higher forms, and clear the path of my earliest studies. Nor was this yet enough, for beyond the world of plants there lie in wait still simpler substances, minerals and elements. But this is a boundless task and all too vast for my strength.

Here the indomitable urge to know, the keynote of the career of Marcello Malpighi, which set him apart from his fellows as a leader of scientific thought and investigation in the seventeenth century.

Born on March 10, 1628, at Crevalcore, near Bologna, the son of well-to-do parents, Malpighi was educated in his native city. After a few years of liberal education, at that time the study of philosophy, he entered the university as a student of medicine. There he at once came to the fore, and was a notable member of Massari's group of nine. On graduation he practiced and taught for a couple of years, until his appointment to the chair of theoretical medicine at Pisa. To Pisa he owed his friendship with the temperamental Borelli, and to Borelli his nearer acquaintance with the current problems of physics. After a few years in Pisa, during which his health was far from good, he accepted the chair of medicine in the rapidly growing University of Messina at a salary by no means slender for those days. His stay at Messina has been called by Foster[1] the germinal period of his career. For here it was during a time of comparative peace that there arose in his mind those queries and theories, the attempted solution of which was destined to fill the rest of his career. Already at Messina his name as an original investigator had gone abroad, and he had been invited to join the recently inaugurated Royal Society of London. Four years later, while on a visit to his native city, he was claimed by the Medical Faculty of his Alma Mater, and was released by Messina only with much protestation and regret.

> I then arranged my domestic affairs in Bologna, and set to work in a frame of mind at the same time calm and keen. My time was absorbed by reading in the forenoons, and in looking after my patients in the city and in the country. I attended dissections, and all the time from an examination of the living and a study of the dead, I tried to fathom the causes of disease. Meantime I kept up a constant intercourse with my friends, especially those from abroad who happened to be passing through Bologna . . . and in discussion I tried to learn more of anatomy and of the remedies for disease. . . .

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[1] Foster, Sir M. "Lectures on the history of physiology," 1901.

This last remark is characteristic of the unassuming simplicity of the already famous scientist.

Brilliantly successful and smooth on the surface as Malpighi's academic life appeared, yet it was not without its untoward happenings. Frail health constantly hampered his activities, and the life-long vendetta of the Sbaraglia family, also resident in Bologna, was a constant source of strain. The latter indeed considered it perfectly fitting to molest and to terrorize the aged professor and his wife when they were living with but scant attendance in the country.

At the age of sixty-four years, Malpighi was uprooted from his beloved Bologna and was summoned to Rome as papal physician to Innocent XII, which position he held until his death three years later, in 1694.

From the incessant demands of the dual life of physician and teacher, Malpighi was wont to retreat to the country whenever possible, passing the time occasionally with friends, but for the most part in his own home. There "freed from the troublesome practice of medicine," he could enjoy the "peace of the country" and meantime devote himself to the recently invented microscope. To Robert Hooke the microscope had already revealed the structure of cork, to Leeuwenhoek animalcules many and various. Naturalists both were these, discursive in their interests and observations. The microscope was in sooth a pretty toy, and there were very many things to be seen in the world at once curious and delightful, if, be it confessed, at times a trifle disconcerting. In the hands of Malpighi, trained anatomist and physician, the microscope with its ever-increasing intensity of vision, became at once an instrument instinct with power.

In the seventeenth century, an age of incipient realism in science, the authority of the written word was early doomed. To see with the bodily eye was to believe, and the comfortable faith of an earlier day in the world of spirits, natural, animal and vital, passed straightway into a slow decline.

In no field of science was the turn of the tide more manifest than in the theory and practice of medicine. The circulation of the blood, enunciated clearly, and for the first time proved by Harvey, was further corroborated and supplied with an accurate physical foundation by Malpighi's discovery of the capillaries. Nutrition, respiration, excretion and reproduction, in short all the functions of the body, can only be considered in reference to the circulation of the blood. Thus a new trend was given to current medical thought. Ferments luckily there still were in plenty to serve.as the ever useful unknown quantities responsible for the specific functioning of individual organs. Ferments and the process of fermentation, the latter akin perhaps to the bubbling of fermenting wine, or again perhaps to the chemical exuberance of interacting acid and chalk, served their day and generation, until, on meeting the nemesis of a subtler chemistry, they passed along, even as their more spiritual forebears, to the limbo of concepts forgotten.

While these same ferments were playing their part on the scientific stage, muscle fibers and nerves, veins and arteries, capillaries, glands and their ducts, lymph vessels and lacteals, with the aid of scalpel and lens were being distinguished each from each, and anent their exact function many theories arose.

It is not within the scope of this paper, however, to discuss the work of Malpighi, physiologist, anatomist and histologist. Primarily physician, as we must perforce acknowledge him to be, yet nothing, we find, is beyond the curiosity of Malpighi, biologist. The Royal Society in the fever of its youth is interested in receiving communications on all possible subjects of scientific interest, and Malpighi is numbered among their untiring correspondents. And the work of his hand and brain is not "of the stuff that dreams are made of." A multitude of careful diagrams and a wealth of experimental detail give to his scientific foes data sufficient to repeat his work and thereby to corroborate or to refute his statĕments. And so we find him discussing now the structure of the lungs and the nature of blood, now the viscera of the higher and lower animals and the histology of glands and bones and teeth. He enquires into the sense of taste and of touch and the nature of the grey matter of the brain. The anatomy of the silkworm is one of his earliest studies and the firefly at a later date excites his wondering admiration. And ever and anon he busies himself with the nature of plants, their structure and economy, their growth and reproduction, the "seeds" of lichens and mosses and ferns, the habits of parasites and climbing plants, the marvelously curious insect galls and the disturbances they cause in the normal nutrition of the plant. Nor must we forget Malpighi's contribution to the foundation of embryology, a detailed account of the development of the chick.

It is during his stay at Messina apparently that his interest in the structure of plants is thoroughly aroused. The breathing of insects is accomplished by means of slender tubes, exact miniatures of the windpipes of the higher animal and hence called tracheae. What can be more significant than the fact that, in a chestnut twig there are visible these very same tracheae? And the rest of the plant body, what of that? Where are the counterparts of animal viscera and reproductive organs?

Throughout the whole of Malpighi's botany there is working the mind of the biologist, secure in the belief that all living things are similar in their functioning, and that in plants and animals, therefore, there are to be discerned equivalent structures. A zeal for pretty comparisons here carries Malpighi somewhat far along imagination's highroad, as in his account of the structure of the seed. But microscopes in those days, be it remembered, though perhaps some eighteen inches high, were not necessarily accurate in proportion to their stature.

Dissection and maceration had accomplished much towards an understanding of animal structure. To dissection and maceration, therefore, Malpighi turns for the elucidation of plant anatomy. Microscopic sections, transverse, longitudinal radial and longitudinal tangential are made "with rude instruments enough," and in the case of certain succulent plants, *e.g.*, the *cactus Opuntia,* the method of maceration is invoked. No part of the plant is spared. Stem, leaf, root, bud, flower, seed, seedling and insect gall, all fall in turn to the dissecting blade. "Nature in building the world of plants is not confined to the use of one scheme only, but underlying her work as a whole there runs a certain thread of uniformity."

So we read as we go on to consider the structure of the plant shoot. Further in particular regard to the stem of the vine:

> A stem consists of two parts, cortex, and wood. (To Malpighi the cortex is that part of the stem outside the woody cylinder, including to-day epidermis and cork, cortex, endodermis and pericycle, phloem and cambium.) In a vine stem a few months old there is present a wide cortex, the outer cells of which have decayed and dried, thus forming an epidermis. The cortical cells vary in shape. Within the cortex there occur various fibrous strands (bast fibers) . . . which strands anastomosing, are seen in longitudinal section to form a net. The meshes of this net are filled with horizontal rows of cells (medullary rays) while the strands themselves are made up of woody fibers . . . very closely packed together. Within the cortex lies the woody part of the stem. There penetrates this the said (medullary) rays. Some of these reach the pith, others fall short of it. The cells of the pith resemble those of the cortex, but may be larger in size. The woody part of the stem consists of a ring of wedge-shaped (vascular) bundles, separated by (medullary) rays, the apex of the wedges pointing towards the center of the stem.

> Tracheae (spiral vessels) of varying diameter, heavily surrounded by woody fibers, . . . along with the intercalary (medullary) rays, are the elements which make up the wood. . . . I was unable in the vine to see any laticiferous vessels. . . .

The parenchyma of the stem consists of "small sacklets or utricles, spherical or oval in shape, thin-walled and filled with diaphanous sap."

The "woody fibers" (of wood and bast) are elongated tubes of varying diameter, whose direction is not strictly vertical, and which open into each other.

The "inner cortex" (*i.e.*, the zone immediately external to the woody cylinder, therefore in the normal position of the cambium) is the most important part of the stem, because in it secondary thickening with the formation of annual rings takes place. The young wood is at first soft in texture, but with the inflow of sap it becomes hard.

The "tracheae" or "spiral vessels" resemble closely the breathing tubes seen in insects, but in place of the rings in these tubes, "the inner surface of the vessel is roughened by a silvery spiral ribbon. When a stem is broken across this ribbon may be drawn out, and if this happens in spring to a young green twig, then a peristaltic movement in it may be observed, and this is a pretty sight. Perhaps the movement of the sensitive plant may be due to this capacity."

Of such elements, then, is the plant built up, elements which recur in leaf, root, flower, bud and seed. To Malpighi, however, anatomy is not an end in itself, but merely a road that may lead towards an understanding of physiology, whether of plant or animal.

"Since plants are placed in the number of living things which feed and grow and beget their kind, their life is as the life of animals. Alike in purpose as in function, nature has endowed both with similar structures."

"In the higher animals new food enters the veins in the form of chyle. Here it mingles with the ferments, the lymph and other substances of the old blood, and in the blood stream it circulates unceasingly throughout the various parts of the body. It is thence recollected, and enriched by the ferments it has acquired, enables the animal functions of nutrition and excretion to be carried on."

Turning to the plant Malpighi notes that it consists of roots and shoot. The roots are buried in the soil, and by the roots a crude sap is absorbed. The roots, therefore, in the lap of the soil, are the viscera of the plant.

> From the roots the crude sap is conveyed in the woody vessels to the shoot. In the (parenchyma) cells of stem (and leaves) it is mingled with the crude sap already present, and becomes exalted to the nature of a ferment-like substance. . . . The process of fermentation is assisted not a little by the heat of the outer air. . . . The elaborated sap may either be retained in the (parenchyma) cells of the shoot, ready for the future development of buds and leaves, or it may pass down to the roots, . . . as it does in the case of those plants which are possessed of bulbs.

The absorption of crude sap by the roots and its elaboration in the shoot are then, according to Malpighi, the essentials of plant nutrition. That this manufacture of food is carried on in the green cells only, is the discovery of a later day.

From a consideration of structure Malpighi reaches the conclusion that, while food elaboration is vastly important, it is not, however, the sole function of the leaf.

> To what parts of an animal do the leaves correspond? . . . obviously not to the muscles, since plants do not move from place to place. . . . Nor to the entrails, since the alimentary canal deals with chyle preparation, a function of the plant roots in the lap of the earth. . . . possibly then to the skin? . . . For the animal skin is a tissue of nerves and veins and arteries, lymph vessels, tendons and glands, a tissue permeated by nutritive sap. . . . This sap, through the glands, gets rid of waste material, and meantime also acquires new ferments. From the skin it returns to nourish the inward parts of the body.

> The leaf is a tissue of tracheae and fibers and special canals, and on the surface, there are glands in abundance and also hairs. The whole is suffused with nutritive sap. . . . From the glands and the hairs there escapes the waste of sweat and slow humors. . . . Thus purified, the thorough cooking of the liquid makes it a more perfect food.

A further analogy between leaf and skin is seen by Malpighi in the lower animals. Insects, for instance, during growth, frequently shed their skin. This is paralleled in trees by the annual fall of withered and useless leaves.

The means by which water enters the root, and once admitted, how it mounts to the tip of the highest tree, are intricate problems then as now.

> The roots of the plant are buried in the soil and serve for anchorage and absorption. They branch repeatedly and end in fine capillaries. The youngest roots are covered with a fur of soft root hairs to which soil particles adhere very closely. . . . As water percolates through the soil, the salts in the soil are dissolved. . . . How these liquids are absorbed is still in doubt. Where are the gates or open mouths through which the rising liquid is strained? . . . Perhaps the root hairs, very delicate open tubules, pass the fluid inward to the woody fibers, or perhaps, when root hairs are absent, water is absorbed by the skin, and passed thence to the underlying cells. . . .

Changing temperature, with ensuing rarefaction and condensation of the air causing intermittent pulsation, . . . is mentioned as one of the factors in the ascent of sap and the roughness of the inner surface of the vessels is also considered as of interest in this connection.

All living things breathe, insects by tracheae, likewise plants. To what end this apparently indispensable respiration?

> So necessary is respiration to life that nature has endowed all orders of creatures with instruments called lungs. Analogous as are these organs, yet they are not wholly alike. . . . For in these animals which we term "higher," the lung capacity is less than it is in the "lower" forms. Man, for instance, in common with other quadrupeds, has two lungs, through which the blood is constantly streaming. In birds the abdominal cavity functions also in addition. With regard to fish, nature is equally industrious, for they are furnished with many rows of gills. . . . Nor are there lungs wanting in shellfish and crustaceans, and here they are often seen to be bigger than the rest of the animal's body. In the latter, of course, respiration is carried on in the water. . . . Coming now to insects, still lower in the scale, we see that the surface of the lung far exceeds that of all the other parts. In butterflies, for instance, I have made out eight or ten lungs which are not, as in us and other air-breathing animals, confined to their proper cavity, but are in the form of long winding tracheae, . . . which ramify like blood vessels in every part of the body. . . . These lungs, present throughout the whole kingdom of living things, are bathed within and without by various fluids. From these they extract the fundamental essence of life. This is furnished to us and to the rest of the higher terrestrial animals, also to the insects, by the air. . . . Fish, crustaceans and other water things extract this breathing substance from the water. . . .
>
> Now since plants are lower than the least of the animals, . . . therefore in them is seen a lavish development of tracheae, . . . penetrating all the minutest parts of the plant, with the exception of the cortex.
>
> We may assume from this that plants, living organisms with their viscera fixed in the ground, must here obtain the material for their respiration, or rather from the air and water that is percolating therein, . . . and that their tracheae are thus filled with the breath of the soil. . . . In regard then to the lungs of the plant, . . . it is probable that the woody fibers, which cling like ivy to the tracheae, and perhaps also the cells of the (medullary) rays, receive the essential breath from the tracheae. . . .
>
> Air openings (stomata) in leaf and cortex I have searched for long and diligently, but without success.

The significance of the lenticels which he describes in the stem of the elm, is apparently not understood by Malpighi.

> I can not clearly understand the meaning of respiration, unless it be that in it is liberated an active substance which serves to keep the sap in a continuous state of solution and fermentation (a condition necessary for growth). This office in animals is effected through the circulation of the blood. . . . At the same time the precipitation of the various salts present in the plant vessels is prevented. . . . Since breathing is as necessary for the plant as for the animal, the gardener works the soil around the plant roots that air may be admitted.

Nor is it only in nutrition, excretion

and respiration that analogies are sought for in the world of living things. In regard to reproduction we read that

> To the animal world nature has given two sexes. One of these produces the ovum and the yolk. The other discharges a substance which may contain some active principle, which determines the growth of the embryonic parts, and as if magnetically, controls the direction of their development.

In plants, however, the case is somewhat different.

> For here there is less specialization of organs, and the essential elements of the whole are present in each smallest part, so that any branch which is cut off, may give rise to a new plant. . . . As an alternative method of reproduction, nature, in the guise of seeds, may bring forth deciduous and miniature plantlets. . . . These may be regarded as pendulous and deciduous buds, capable of germination in a new ground.
>
> The plant egg or ovum is concealed in the uterus (ovary) . . . surrounded by stamens and a floral envelope. Aeration of the egg may be facilitated by the hollowness of the tube (stigma and style) . . . and the entrance of noxious insects may be prevented by the secretion of a sticky fluid. . . . In this fluid are excreted also the impurities of the sap. The pollen dust is likewise a mere excretion, . . . prior to the maturation of the ovum, . . . and may be compared perhaps to the menstrual discharges of women. . . . The floral leaves may function in the elaboration of food for the ovum, just as do the vegetative leaves in the case of the axillary buds.

Meantime in Tübingen Camerarius is engrossed in the problem of the sex of plants.

> In the almond as the uterus (ovary) increases in size, the perforated tube (stigma and style) gradually withers. . . . Within the uterus are at most two ovules (complete with integument and nucellus) in the center of which lies the embryo sac. . . . Growth in the ovule is accompanied by a hardening of the fruit wall. Within the ovule Malpighi now discerns amnion and umbilical cord. The former as we describe it to-day is apparently the beginning of embryo and endosperm, while the latter, a slender thread, is what remains of the embryo sac.[3] Soon the embryo becomes a distinct plantlet with two cotyledons, and grows at the expense of the amnion and the now developed chorion (endosperm and nucellus probably).[3] Food is conveyed to the plantlet for a time through the umbilical cord. In certain ovules, however, this is absent, or temporary only in appearance, and in these cases food is transferred from chorion to amnion and thence to the embryo cotyledons and thereafter to the developing shoot.

"But the development of the plantlet from the ovum seems still to be one of nature's secrets." And Camerarius's contribution to the knowledge of this question only appears after Malpighi's death in 1694.

Notwithstanding the somewhat far-flung analogies of Malpighi in regard to seed development, in his experimental work on the germination and subsequent growth of the seed, his feet remain, for the most part, firmly fixed on the ground. His experiments with varying culture solutions, many of them drastic in content, are less illuminating.

In animal physiology at this time, as has been already said, interest centers chiefly around circulation and the consequent nutrition of the body. That Malpighi, in his consideration of the physiology of the plant, should follow along a similar line, appears therefore to be perfectly logical. Circulation, nutrition, excretion, respiration and reproduction are functions closely interrelated, answers to some of the riddles of which may be sought perhaps in the development of the seedling.

The seeds of various plants, including Lupin, broad bean, castor bean, radish and many others, are planted in a suitable soil, watered and tended and observed with the utmost care from day to day. The function of cotyledons in the plantlet's economy is to Malpighi the mainspring of the problem of growth. He therefore amputates one or more cotyledons at earlier and later stages of seed-

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[2, 3] Marcellus Malpighi, "Die Anatomie der Pflanzen." I und II Theil. 1675 und 1673, bearbeitet von M. Mobius. (Ostwald's Klassiker der exakten Wissenschaften, Nr. 120).

ling development and notes the results. The loss of both cotyledons immediately brings about the death of the seedling. If one cotyledon is allowed to remain, the young plant may slowly achieve a stunted and unhealthy growth. From these early experiments Malpighi concludes that the seminal leaves of the seedling are necessary for the early nutrition of the plant.

> Water as a substance is inert, but in the soil it dissolves certain salts, similar to those found in the plant, . . . and acts as a vehicle for them. The water then which enters the seminal leaves (from the roots) is not simple and pure, but contains salts both volatile and nitrous. . . . A hardened sap lies stagnant in the seminal leaves . . . aqueous particles now enter, and with the salts they bring . . . yield a mixture which becomes the sap proper for the development of seedling and root.

This point of view runs counter to the opinions of Malpighi's former colleague, Borelli, and also to those of Triumphettus, a most persistent, if not always a particularly astute, critic. Malpighi at once sets about to defend, and by further experiment, to reconfirm his theory. Borelli, relying on animal analogy, objects to the whole idea of food elaboration. Since plants have no means of excreting waste, he maintains that they must absorb their nourishment pure and perfectly prepared for their use. Triumphettus points out that the wounding and the consequent escape of sap may be the cause of the unsuccessful growth of mutilated seedlings, and mentions further the interesting fact that, if the wounds are sealed with wax or were covered with earth, the experimental plants will succeed perfectly.

Malpighi is not entirely convinced.

> I confess that after reading this (Triumphettus' letter) I was for long in serious doubt until, when the opportunity came along, I repeated the experiments, with the wax sealing used by Triumphettus; then I became certain that he was mistaken, and that the seminal leaves are really necessary to the seedling's growth.

So we find that in the early spring of 1685 Malpighi makes a long series of careful experiments. These he repeats and more fully in 1687, keeping a daily record of the plant's growth. Thus of the castor bean, we read:

> After the fifth day the seedling was longer and larger, and the decaying cortex (seed coat) was still sticking to the seedling. The root was already thicker, . . . and beyond the root hair zone were seen the beginnings of secondary roots. . . . The plantlet within was developing thicker and wider leaves, yellowish in color, in which the veins were distinct. . . . The plantlet could easily be separated from the placenta (endosperm). . . . After the eighth day the leaves, now a thumb's breadth wide, have unfolded, and are green in color. . . . Between these lies the bud, made up of compact foliage leaves. . . . and so through the month growth continued, the number of nodes increasing. . . .

The results obtained once more confirm Malpighi in his theory of the function of the cotyledons.

Plant nutrition, then, in its widest sense, depending on an understanding of plant anatomy, and on experimentation, is the main theme of Malpighi's work. But the controversy of the day does not by any means run along in a single channel. The question of the fixity of species is raised by Triumphettus, who maintains that wheat of its own accord has been known to change into tares. Malpighi is unable himself to observe such a metamorphosis but indicates the range of possible variation within a single species, from his observations of the behavior of plants in cultivation and also of certain monstrosities presumably caused by disease.

That all plants arise from preexisting seeds Malpighi firmly believes, but many people are of the opinion that the earth from its own substance can bring forth living things. So we find Malpighi proving by experiment, to his own entire satisfaction, that this theory of spontaneous generation is an unsubstantial myth. No living plant is produced from soil alone, soil taken from a distance below the surface, enclosed and protected from wind-blown seeds in a covered glass vial, even when this earth is watered and kept at a suitable temperature.

Some who delight in the theory of preformation are courteously advised by Malpighi to turn to the microscope, and with an open and unbiased mind to devote themselves to a study of the tissues of the embryo plant. Is not the human embryo in its earliest stages, though seen to be utterly devoid of bone and muscle and many other parts, nevertheless the essence of man?

And all this work on plants is the hobby of a doctor of medicine, of one who, in research along his own professional line, has made some of the most far-reaching discoveries in the history of physiology.

> The work of a man unaccustomed to the study of botany, as he modestly remarks in his all too brief autobiography, a man distracted by other work, whose peace was broken by the more serious charge of attending the sick . . . a work undertaken not that it might throw open new fields of learning . . . but that it might serve to soothe the weariness of a physician's life.

That it is, however, of importance to science as a whole, Malpighi does not for a moment doubt. In his latest writings we find him descending heavily on those practical medical men who scoff at the folly of a non-utilitarian research. "Does then medicine in its theory and practice owe nothing at all to the world of plants?"

There are many points in Malpighi's scheme of things and in that of his English compeer and contemporary, Nehemiah Grew, which the veriest tyro in a school of botany to-day can glibly criticize and summarily refute. But this fact in nowise lessens the greatness of Malpighi's work. The cycle of absorption, food elaboration and excretion remains a cycle, and respiration is still a necessity of life. Meantime the essentials of plant reproduction have emerged somewhat from the void of the unknown. Between animal and plant there is still a fundamental likeness, for the "diaphanous sap of the thin-walled utricles," is the parent of the living protoplasm, and we are looking, from a distance of three hundred years, not at a filigree of exquisite detail but at the vivid and fearless lines of an artist's earliest sketch.

CONSTANTINE RAFINESQUE

By EARL L. W. HECK

"Time renders justice to all at last." These were the last words of "one of the strangest figures that has ever appeared in the annals of science," as David Starr Jordan once said. They were the words of an optimist; one of those who never acknowledge defeat, though for many years his name was buried in oblivion. He uttered these last words in 1840, but it was not until fifty years later that the truth of his prophecy seemed apparent.

It is rare that a great scholar and an ardent pioneer are united together in one person. When the qualities of two such admirable individualities are so combined in the same, no less than a remarkable personage can be expected to result, even though that result be of somewhat negative nature. Such was the case of Constantine Smaltz Rafinesque, "an extraordinary man, with a quaint name and with most unusual parentage." His father was Franko-Turkish; his mother, a Miss Smaltz, was Greco-German; the son, born on the shores of the Bosphorus, became an American professor in the oldest college in the then western wilderness. His father was a French merchant, engaging in business in Constantinople, in which city the son was born and after which he presumably was named.

Young Constantine did not, however, live long in the city of his birth, but during infancy returned to the city of his forefathers, Marseilles. His father must have been a man of considerable property, for we find Rafinesque saying in one of his publications that "he first became conscious of his existence in one of the summer places around Marseilles." Here he was educated, perhaps informally, as he later writes, "It was here among the flowers and fruits that I began to enjoy life, and I became a botanist. Afterwards the first book that I received in school was a book on animals, and I became a zoologist and a naturalist." He undoubtedly was a highly precocious child and the reason for his early downfall may be attributed to a too rapid development of his intellectual powers. Rafinesque's later love of travel came naturally to him, as his family seems constantly to be on the move at frequent intervals between Marseilles and the Mediterranean ports. Thus young Rafinesque delightfully spent his boyhood. At the age of eleven he had started an herbarium. At an early age he read books of Latin and Greek and at times the more entertaining "Narratives of Captain Cook." "I never was in a regular college," he writes, "nor lost my time on dead languages, but I spent it in reading alone, and by reading ten times more than is taught in schools. I have undertaken to read the Latin and Greek, as well as Hebrew, Sanskrit and Chinese and fifty other languages, as I felt the need or inclination to study them." This is Rafinesque in brief; a man a century ahead of his time; yet a trace of the Middle Ages lingers in his strange scholasticism.

But the delightful life between the pleasant gardens of an old French chateau and Mediterranean cruises to well-nigh enchanted isles was not to last forever. France was at war with George III.'s powerful navy and the British cruisers did not make it profitable for the elder Rafinesque's ships. As a consequence, the family came to America—to Philadelphia. That was a year or so before the great epidemic of yellow fever in 1793. The father perished in that great pestilence, and the family was left friendless in a new country. The estate was settled and after all the debts were paid, the family was left in straitened circumstances.

Rafinesque had early learned to like travel. With travel he associated being a merchant. But to be a merchant, as Rafinesque conceived it, required capital and that he did not have, so he decided not to be a merchant.

Soon after his father's death he made the acquaintance of the great Dr. Benjamin Rush, of Philadelphia, who revived his interest in natural history. The two found each other's company congenial. But in 1803 Philadelphia was again ravaged by the yellow fever and Dr. Rush returns to his patients, and Rafinesque departs for the open spaces. The next year or two he spends his time tramping over the hillsides of Pennsylvania and Maryland, collecting flowers, rocks and fossil specimens. Returning to Philadelphia he meets two families destined to play a part in his later life—the Cliffords and the Tarascon brothers, Marseilles merchants, who later settle at Louisville, Kentucky. During the winter he held a clerkship in a mercantile firm, but in 1804 he resigns that post in favor of a younger brother and becomes secretary to a Mr. Gernon. But the call of distant lands and hopes of finding new plants were too strong for Rafinesque and in 1805 he sets sail for Sicily, accompanied by his brother, whom he says in his journal "would follow." This brings out another strange but important characteristic in Rafinesque's personality. His brother apparently meant little to him, although this brother seemed devoted to him. Rafinesque seldom mentions him thereafter. Plants and animals he was interested in and not brothers.

At the age of twenty-two he enters Sicily. There is something of the poet and more of the human being when he speaks of the Sicilian mountain splendor. "The mountains were smiling with flowers and verdue; they invited me to climb over them."

It was here in Sicily that the young naturalist did his best scientific work; but his energetic enthusiasm was counterbalanced by his careless methods of work. He was explosive and he got results. But alas too often were his results hastily and inaccurately drawn.

Various accounts differ as to Rafinesque and marriage. Professor David Starr Jordan, in an article published in the *Popular Science Monthly* for 1885, says that he can find no record of any woman, save his mother and sister, as being connected with Rafinesque's life. Call, however, states that in his will Rafinesque writes: "While residing in Sicily I deemed myself lawfully married . . . although the decrees of the Council of Trent forbade our regular marriage." Two children, it appears, were born of this union, a daughter in 1811 and a son in 1814. The son died the following year and the daughter is never mentioned thereafter except in the will. Whether Rafinesque eventually abandoned his wife and child altogether we can not say, but it is probable they would never consent to share his subsequent wanderings. The flowers of the field and the fishes of the waters again called Rafinesque and he leaves his lovemaking forever to return to the life he prefers. But if Rafinesque errs one way it seems his wife errs in another, because it is reported she marries again when she hears of her husband's shipwreck. In his will he definitely states that in order to inherit his small property his daughter must separate from her mother. This is all we know about Rafinesque's domestic life, and it is perhaps just as well that we know no more.

Rafinesque was somewhat successful

financially in Sicily; "by trading in the products of the island, I made my personal fortune." But he spent the greater part of his ten years in Sicily collecting botanical and zoological specimens, and the extent of his collections must have been enormous. In 1815 the wild shores of America again enticed Rafinesque to them; this time to stay. But it was with ill omens that he entered, cold, penniless and almost clotheless at New London, after suffering shipwreck at the entrance to New York harbor. This disaster had a strange effect on Rafinesque. We might judge from his earlier life that he would have considered this event as of no consequence. If he would have lost only his money and clothes it would have been different. But his collection of natural history of twenty years' labor had gone down with the ill-fated steamer. Things that he had gathered when a boy at Marseilles were among them and things he valued most. Nor did he have the friends who gave him sufficient sympathy. He grew vindictive and asocial. Fortunately at this time his friend Clifford came to his aid and encouraged him to begin another collection. Furthermore, he procured for him the post of professor of botany and natural history at the New Transylvania University, then on the edge of the western wilderness. This was the first chair of natural history to be established west of the Alleghenies, and not many had preceded it in the east. In this capacity Rafinesque made Transylvania what to-day we would call famous. Then it appeared to have been infamous. The chair of natural history was new and unclassical and looked down upon. The professcr was eccentric, at times unkempt and was regarded as on the verge of insanity. The dignity of neither the chair nor the professor could much elevate the other but, like barnacles to each other, they dragged each other well-nigh to destruction. Rafinesque held on for six years and while at Lexington wrote the crowning piece of his life, "Ichthylogia Ohiensis," published in that city in 1820. It made the author famous if not rich and at the time was a member of half a dozen of the leading learned societies of the world. Now "Ichthylogia" is one of the rarest bits of middle-western Americana.

When the break between Rafinesque and Transylvania came he left, loading the college with curses, and he took himself at once to the hillsides of Kentucky, undoubtedly glad that he was a professor no longer, but a joyful vagabond.

He continued to investigate and to publish as long as he had the money, but all the while sinking deeper and deeper into oblivion. When he died in 1840 he left an elaborate will but little else. At least he died like a gentleman with all his affairs settled properly. Only for the interference of a few old friends was his body saved from a medical college. Now his bones are said to rest in the campus of Transylvania which in older days drove him forth and which in turn he cursed.

Rafinesque was a genius in the best sense of the word; inasmuch as he saw light where others failed to see even darkness. He had learned to solve the problem of material existence and to sacrifice sensual pleasures for those mental and spiritual. He was a pioneer both in spirit and habitation. There is little doubt that he preferred the wild wilderness of the lower Ohio Valley to the refinement of Philadelphia or the gay pleasures of Paris and Marseilles; yet he was equally at home in both, or at least he never felt himself out of place in the latter, although many may have thought so, shallowly judging from his queer dress.

But as a genius, Rafinesque lacked those qualities of the common man which go toward recognition and worldly success. He delighted in flowers and went into ecstacies when Audubon showed him a new plant. "Not only a new plant but a new genus, Mr. Audubon," he exclaimed, embracing the great ornithologist. Then the task of describing the new genus! That is where Rafinesque failed. Not that he did not fully understand this new genus nor that even his description was unintelligible to himself later. But his love of introducing novelties and fancy clouded for other scientists what to him was ever clear. But then perhaps only another genius could understand his point of view. Darwin, I believe, did, although there is no record that he was acquainted with Rafinesque's work; but the ideal science Darwin had in mind when he said, "What a joyful life a scientist would lead if he could ever observe and never write," approached very closely the science of Rafinesque. Perhaps Darwin had something more of the common man when he considered it his duty to write his notes carefully for other people to read later. But not so with Rafinesque. Little did he care who read his notes, for he made them for himself. One of the most remarkable instances which clearly shows this utter indifference to the world was in 1820 when he edited a scientific periodical called "Annals of Nature." From the first he was editor and sole contributor; ere long he became sole subscriber, which did not in the least affect the status of Rafinesque's periodical. When, however, he could no longer afford to pay the price of subscription, "Annals of Nature" ceased publication; but it was a case of necessity rather than expediency.

Rafinesque remained a child and from his child-like simplicity came his boundless supply of enthusiasm. How gloriously naive when, as professor of botany and natural history lately exiled from Transylvania, he exclaims with unfeigned vehemence, "I took lodging in town and carried there all my effects, leaving the college with curses both on it and [President] Holly, which reached them both soon after; for Holly died of the yellow fever in New Orleans and the college was burned with all its contents." And undoubtedly Rafinesque, eminent scientist as he was, died with the belief that this malediction was the cause of Transylvania's downfall. Who other than an unspoiled child would have the grace to pull off his shoes and cover up the holes in the heels with the sock part of the stockings before a group of strangers and do it all without embarrassment but actually with charm. But this is what Rafinesque did, the first time in Audubon's house, and before the whole family. "He told us in the gayest mood imaginable that he had walked a great distance . . . and was sorry his apparel had suffered so much from his late journey."

On the other hand, there are times when he displays those qualities which in children we call "pouting" when the individual is out of sorts with the world for little or no reason. "Some hearts of stones," he writes after his shipwreck, "have since dared to doubt of these facts or rejoice at my losses. Yes, I have found men vile enough to laugh without shame at my misfortune instead of condoling with me!" But he is fair with himself when he admits, "There were also friends who helped me in my distress."

Peculiarly enough the shipwreck did leave a visible mark on Rafinesque's later life. What an ordinary man would soon forget or at least learn to look back upon the event not without humor, Rafinesque took to heart and bewailed his loss for years to come. Although only thirty-two years old, he thought he was too old to begin again, and his scientific writings from that time on showed a steady decline, to rise for only once in his "Ichthylogia."

It is either very comical or very pathetic when Rafinesque describes in a scientific paper a series of most unusual fishes which are said to inhabit the lower Ohio River and painted by Audubon; and the illustrations given to Rafinesque and described as real by Audubon in retaliation for the destruction of the latter's favorite violin on the part of Rafinesque, who used it for killing bats once while visiting the great ornithologist at Henderson.

It would speak well for Rafinesque if his friends could prove this joke played by him on other naturalists. But there is very little reason to believe this is so. When we remember his love for introducing the unusual, it seems we must admit this to have been done in all scientific seriousness.

Rafinesque was not an Agassiz because he had not that fine discriminating eye and mind. But Agassiz thought well of Rafinesque and spoke well of his work, and adopted many of his classifications. Perhaps Agassiz would not have been the great naturalist which he was had it not been that Rafinesque had partially paved the way. If there ever was a scientist "crying in the wilderness" Rafinesque was that man.

But there is another reason why Agassiz has ever been at the acme of scientific reputation and Rafinesque at the lowest. All Europe and America mourned when Agassiz died, but Rafinesque died obscure and poor. But what a difference between the two men. Agassiz loved the men and women of the world and in turn they loved him; Rafinesque lived for himself, alone, lovingless and unloved. Agassiz was a great personality; Rafinesque a great mind, the mind of a genius, perhaps, but still only a mind.

TWO-HEADED SNAKES

By BERT CUNNINGHAM
DUKE UNIVERSITY, DURHAM, N. C.

THE two-headed specimen of the spreading adder which initiated this study came into my possession in an unusual manner. It was discovered by men who were making a run of illicit liquor when the small reptile came up to the fire either from curiosity or to warm itself. The men, fearing that their senses were fooling them, captured and preserved the reptile in their brew in order that they might observe it under more favorable conditions. The specimen was lost to science when it had to be returned to its owner to settle a bet. The route by which the specimen came to me was so indirect that I have been unable to trace the original ownership.

However, good use was made of the specimen while in our possession. Photographs were made of the external appearance and X-rays were made of the skeleton. These are shown in the accompanying figures. (See Fig. 1 and Fig. 2.)

Through the kindness of Dr. E. W. Gudger, of the American Museum, and Mr. C. S. Brimley, of Raleigh, N. C., some references to the literature of the subject were secured. With these as a basis, the writer has been able to secure a rather extended bibliography. Although the many references to this phenomenon are scattered, there have been two rather exhaustive papers published upon this condition—the first by Johnson in the *Transactions* of the Wisconsin Academy in 1901, and the other by Strohl, which was published in 1925 in the *Annales des Sciences Naturalles Zoologie.* Both of these articles carry good bibliographies which are remarkably supplemental.

Animals possessing two heads have been described in two ways. Among these there are those which are reputed to have a head on each end of the body, and there are those having multiple heads on the anterior end of the body.

Among the first are the snake-like lizards, that is, lizards without legs, to which belongs the genus *Amphisbaena.* (See Fig. 3.) These animals are nearly the same diameter throughout their entire length. When disturbed, they have the peculiar habit of elevating the tail in much the same manner that a snake does its head. Ditmars in describing the animal says, "The tail is just as thick and stumpy as the head; unless one examines the animal closely, the two extremities can not be told apart," and further, "When a specimen was annoyed it would elevate the stubby tail in a fashion that caused the organ to look like a head reared in threat; at such times the head remained flat upon the ground unless the body was pinched: then the head swung about for the offender." They are also reported to have the habit of running backward with the same agility as they go forward. Hence the name. With these two habits combined, one is not surprised to find that some observers thought the animals possessed of two heads. There is also a group of snakes having somewhat similar characteristics, the *Eryx johnii.* The Hindoos painted a mouth and eyes on the blunt end to make the appearance of two-headedness more conclusive.

The *Amphisbaenas* (the snake-like lizards) were considered as extremely poisonous according to Bancroft. This writer pointed out the improbability of the *Amphisbaena* having two heads since "there is no animal in nature that is thought to have two heads." In a footnote to this sentence he reports and figures a genuine dicephalous case (see Fig. 6) occurring in a specimen from the Lake Champlain region, which he designated as an *Amphisbaena.* This animal is in no wise similar to *Amphisbaena,* but is rather to be grouped with those having anomalies of development which are now to be considered.

Of the snakes having the dicephalous anomaly, there have been from twenty to thirty cases reported, ranging from those having skulls but slightly separated to those having necks of considerable length. (See Figs. 4 and 5.) In some the ribs from one vertebra fuse with those of the vertebra lying opposite. This may be observed in our specimen (see Fig. 2) as well as in *Pityophis sayi* (see Fig. 4). It can also be seen that in our specimen the bifurcation begins with a Y-shaped vertebra.

The internal anatomy of some of the specimens has been studied. In all cases it is to be supposed that the alimentary canal is double for some distance, although we did not demonstrate this in our specimen. Both mouths are reported as functional, and it has been observed that when one mouth has eaten, the other ceases to be hungry. However, both heads will attempt to swallow the same morsel. In a case reported by Lessona, there were two sets of lungs present, although three of the four were atrophied; there were also two livers, one of which was larger than the other; the heart also was paired.

Although most of the specimens reported were small and presumably young, some virtually newly born, Lessona cites Redi as having had in his possession an adult snake having two heads.

Since nature does not often produce such monsters, it is legitimate to ask why does she produce any. It is comparatively easy to understand why placental animals become twin monsters, and the spina bifidal effects of pressure on frog eggs, but what can happen to a hen's egg that would make it produce a four-legged, three-winged monster is a mystery. The same might be said with a reasonable degree of assurance about the snake egg.

One of the more common explanations is that the phenomenon is due to a double yolk. Double yolks may be responsible, but I have seen two turtle embryos (*Chrysemys marginata*) on a single embryonic disk. They were small, about 4 mm., but apparently perfect. It would not take much imagination to see them fuse into a two-headed monster with a single body.

Another explanation is that the condition is due to pressure. Pressure effects would in all probability depend upon the rigidity of the shell. Certainly in chicks this would not be the cause, for it has been shown that chick embryos produced under increased atmospheric pressure show no more anomalies than those produced under normal pressure. In such animals as *Chrysemys marginata* where the shell is flexible the turgidity is so great that considerable external pressure would be required to produce any effect.

The possibility of two germ nuclei in a single embryonic disk, or the separation of the blastomeres produced in first cleavage with independent development for a time and later a partial fusion, seems more reasonable, although neither of these explanations is wholly satisfactory.

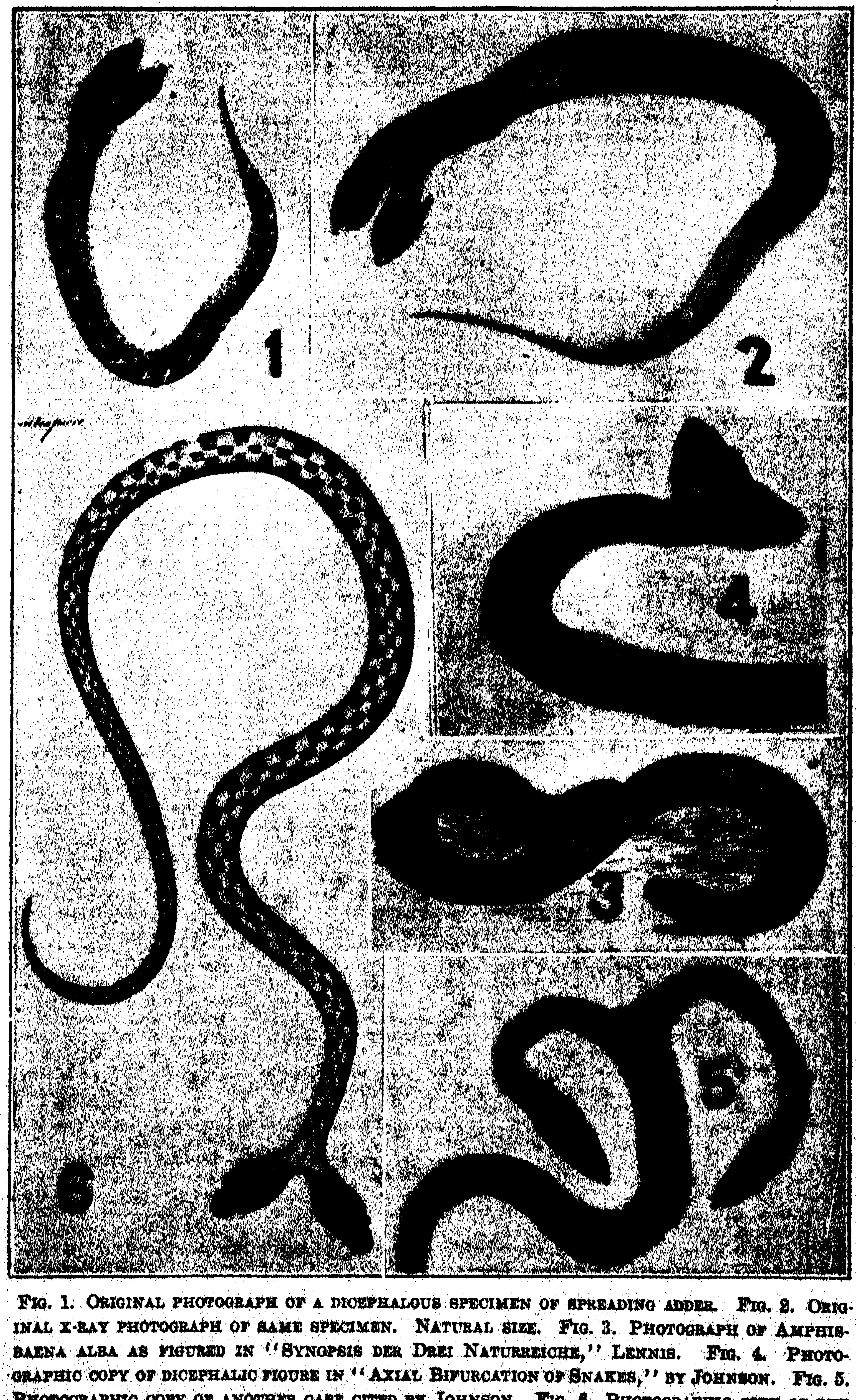

Fig. 1. Original photograph of a dicephalous specimen of spreading adder. Fig. 2. Original X-ray photograph of same specimen. Natural size. Fig. 3. Photograph of Amphisbaena alba as figured in "Synopsis der Drei Naturreiche," Lennis. Fig. 4. Photographic copy of dicephalic figure in "Axial Bifurcation of Snakes," by Johnson. Fig. 5. Photographic copy of another case cited by Johnson. Fig. 6. Photographic copy of the "Amphisbaena" figured by Bancroft. Figures 4 and 5 illustrate the wide differences in bifurcation.

A TWIN TURTLE

By Professor **S. HOFFMAN DERICKSON**

LEBANON VALLEY COLLEGE

EXAMPLES of twinning with various degrees of union of the two individuals is fairly common among the vertebrates, although more frequent in some classes than in others. They are not so common, however, as to pass unnoticed.

One of my students, Mr. V. Earl Light,[1] brought in for my inspection a twin painted turtle, *Chrysemys picta,* which he had borrowed from a neighbor. The specimen had been found several years before by the neighbor's little daughter near an abandoned canal a few miles west of Harpers, Lebanon County, Pa., in the early summer. The child was attracted by its peculiar appearance and ungainly ways and took it home. Her mother put it in a jar on the back porch of the farm house, where it lived in spite of lack of proper food and the heat of the afternoon sun beating in on it for about three months. It was the curiosity of the neighborhood but failed to fall under the attention of any one inclined to make a critical study of its behavior and give it proper care and attention. Accordingly, one hot afternoon in August it died, probably from a "complication of conditions."

Some months ago I visited the family in company with Mr. Light and from their recollections we gleaned the following concerning its behavior: It could swim and handle itself in the water very well. It was given various kinds of food, bread, meat, vegetables, fruits, etc., but was never seen eating, although they supposed that it ate some of the food placed in its jar. When placed on the ground its movements were more awkward. Sometimes the movements of the front feet seemed to be coordinated, but usually they appeared to act independently and with contrary movements. Likewise, the heads sometimes agreed but more frequently disagreed. It is indeed unfortunate that it did not fall into the hands of some one who would have kept it under observation in conditions where it might have lived and provided an interesting record of its behavior.

The accompanying photographs made by the author show most of the peculiarities of its external structure. The radiograph, rather indistinct on account of the youth of the specimen and the manner in which it was preserved, reveals a few facts concerning internal structures. Permission could not be obtained from the owners to dissect and examine the internal structures, as they hope to obtain a fabulous price for the specimen, which we found had been preserved in vinegar and salt in a pint jam jar.

The extent of fusion, or separation, whichever the case may be, affected the different regions of the organism quite differently. The anterior, including the head and neck, consists of two almost perfect duplicates. The dorsal region consists of two carapaces not quite complete. The adjacent margins of the two are bent dorsally and form a prominent median ridge seen in Fig. 1. The marginal plates of the two are fused at the top of this ridge. The base of the ridge consists of the right and left costal

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[1] Light, V. Earl, "A Double Turtle of the Genus Chrysemys." Proceedings Pennsylvania Academy of Science, Vol. 1, 1925.

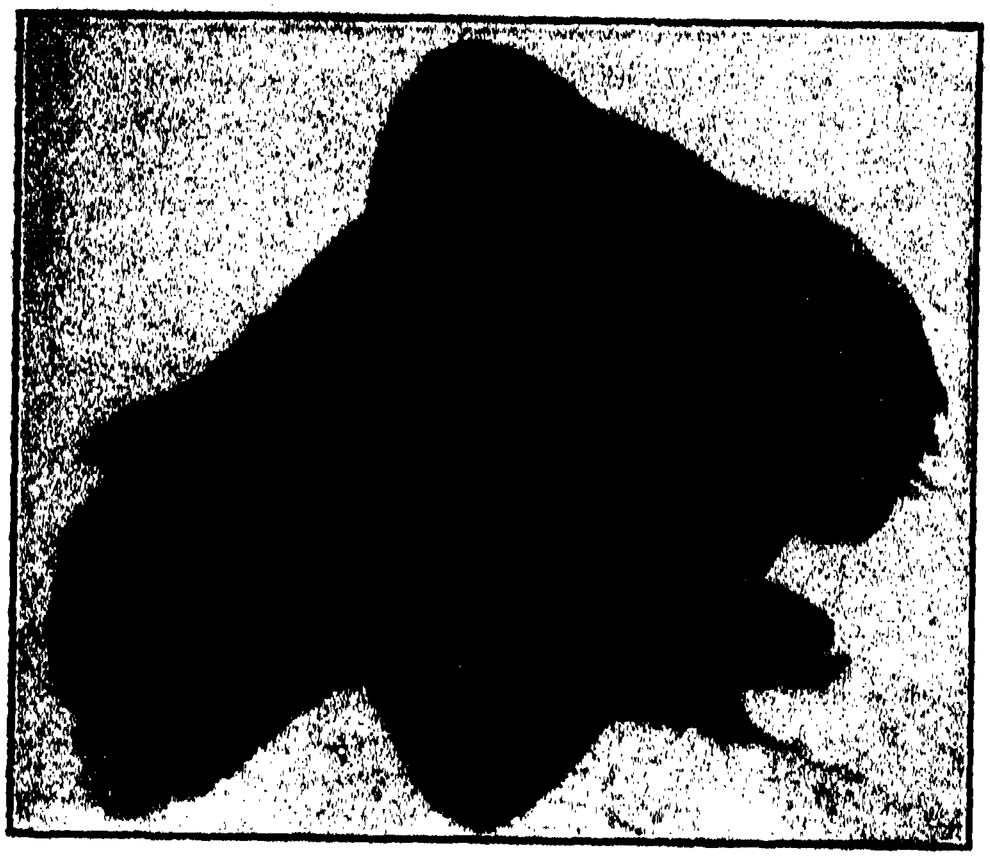

FIG. 1. ANTERIOR VIEW OF A TWIN TURTLE, CHRYSEMYS PICTA.

plates of the two individuals with their ventral surfaces in contact and fused. The ridge does not extend to the posterior margin but ends in front of a plate which resembles a normal neural plate in form and position, although each carapace contains the usual five neural plates in addition to the plate in question, which is apparently an extra neural. Mr. Light interpreted this as an extra costal plate. Posterior to this extra neural plate the twelve marginal plates of the left side of the left carapace are separated from the twelve marginal plates of the right side of the right carapace by the usual pygal plate, below which the single tail protrudes. The posterior aspect resembles that of a single normal individual. The fused margins each present eleven marginal plates, the eleventh pair form the posterior limit of the ridge referred to in a preceding paragraph and are immediately in front of the extra neural plate, which therefore takes the place of the twelfth pair of marginal plates and may be formed by the fusion of the elements which should have normally produced marginal plates, as is indicated by their color markings. The coloration in general is typical of that of the species; there are, however, a few exceptions which are of interest. The fused marginal plates which form the ridge previously referred to are without the usual red spots. The nuchal plates, normally without red markings, here are spotted with red-like marginal plates. Both of these color differences may be interpreted as indicating that color development is influenced by the general symmetry of the organism as a whole rather than by the development of a specific morphological unit.

Two other abnormalities appear on the epidermal plates of the dorsal side. The fifth neural plate on the right carapace is reduced in size and triangular in shape, due to the protrusion of the posterio-lateral angle of the neural plate in front of it. An extra costal plate appears on the left side of the left carapace posterior to the usual four which it resembles in form but is much reduced in size.

The median elevation extending from nuchal plate to pygal plate on a normal turtle is evident on both carapaces, as

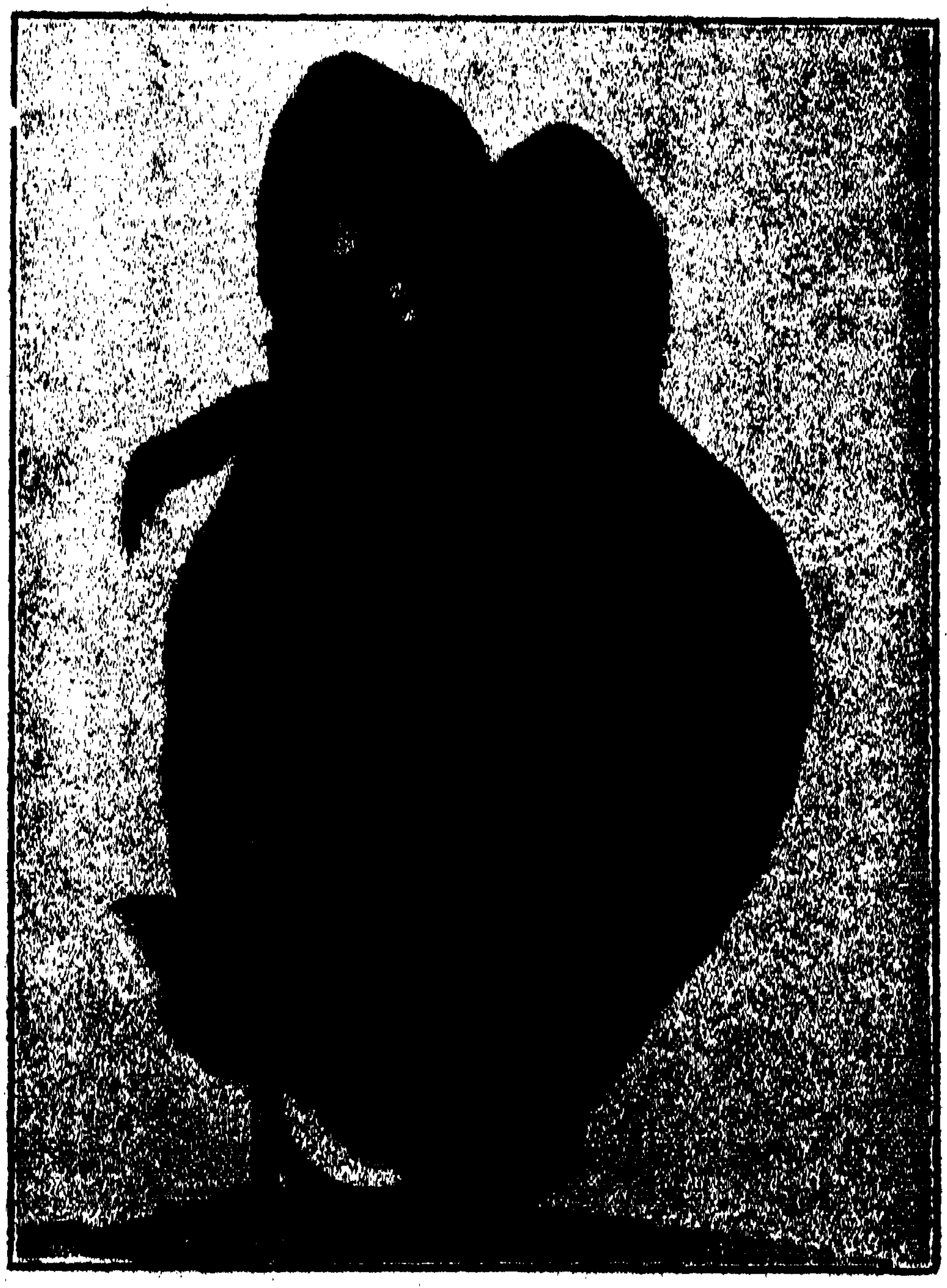

FIG. 2. DORSAL ASPECT OF A TWIN TURTLE.

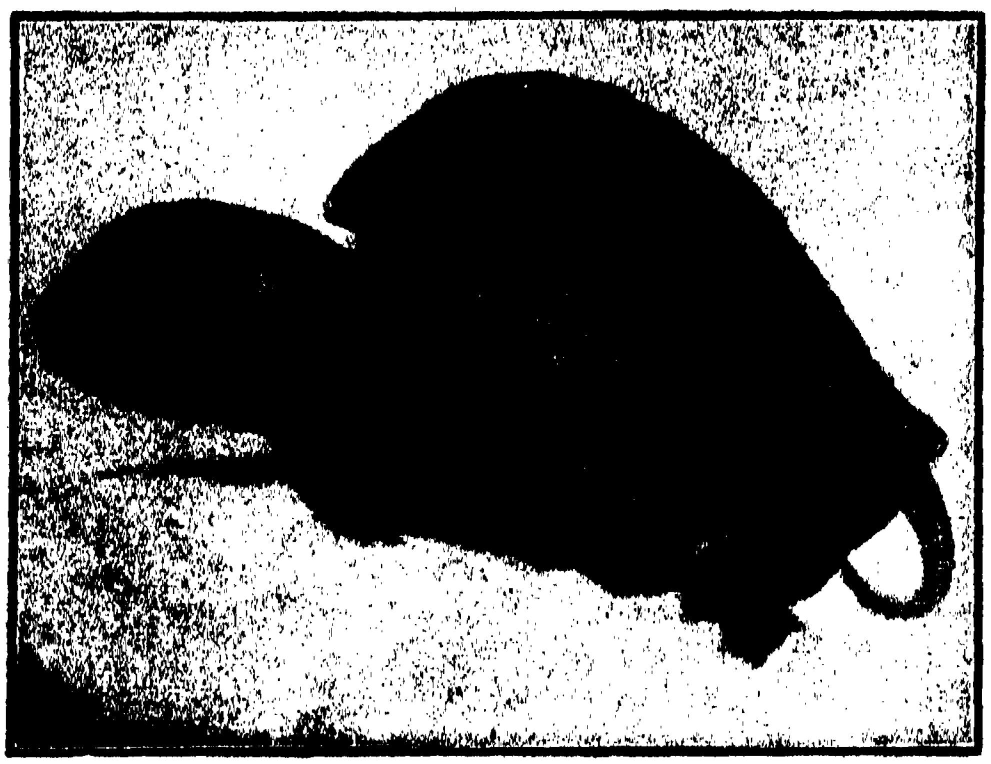

FIG. 3. LATERAL VIEW OF TWIN TURTLE.

may be seen in Figs. 1 and 3, but are not as prominent as on the normal specimen.

The ventral portion of the body seen in Fig. 4 shows little evidence of twinning. A small triangular plate is wedged in between the two gular plates, slightly increasing the width of the anterior end of the plastron.

A mid-ventral scar, possibly indicating an abnormal yolk sac withdrawal, is seen extending posteriorly.

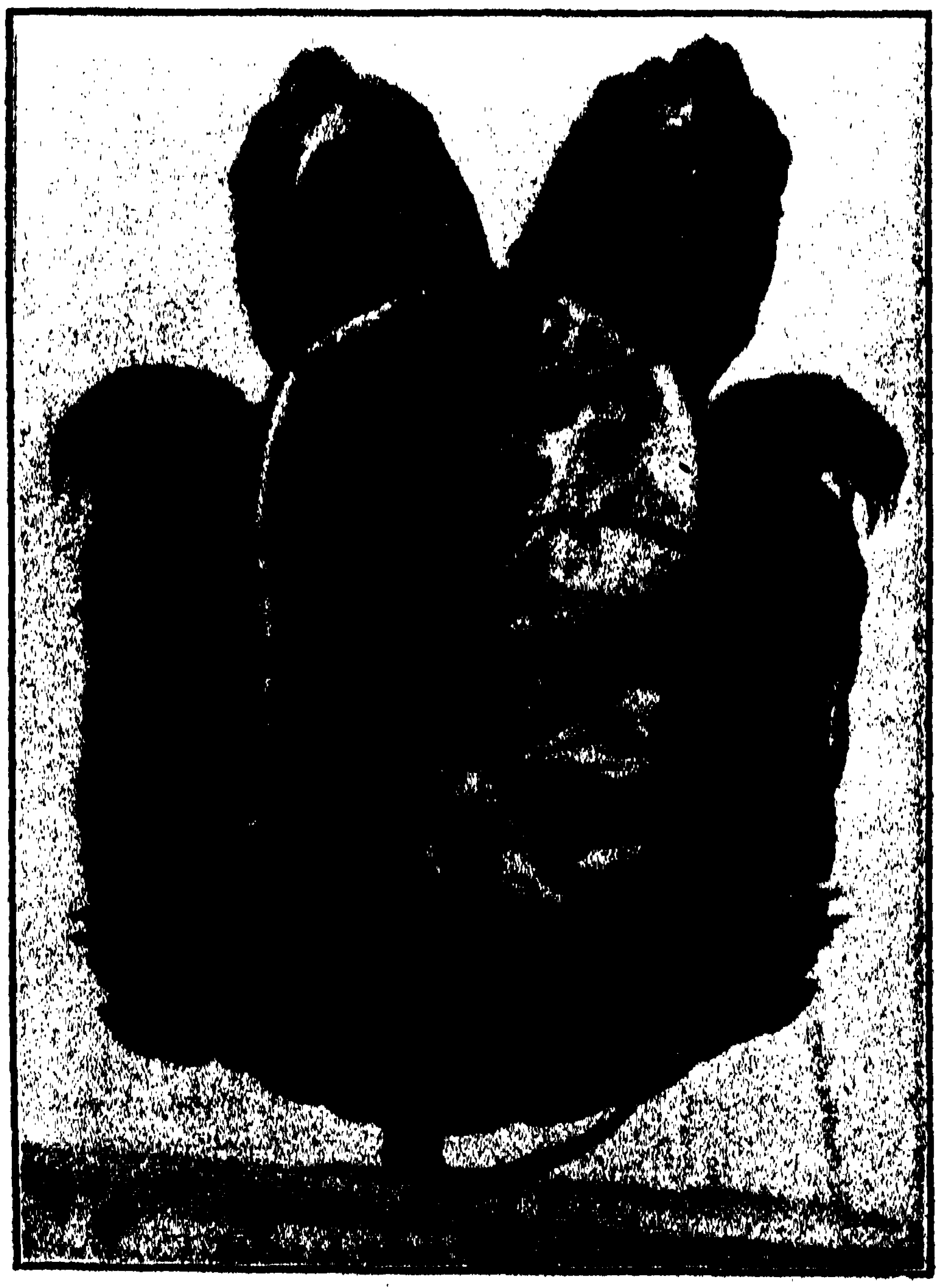

FIG. 4. VENTRAL VIEW OF TWIN TURTLE.

The endoskeleton shows more extensive twinning in the interior of the body, as is shown in the radiographs in Fig. 5.

There are two vertebral columns back to the sacrum and a single column continued into the tail. The pectoral girdle appears to be formed in duplicate also, although the adjacent parts, if present, are greatly reduced. If the adjacent front legs are represented at all, they are so greatly reduced, or lacking in ossification, that they failed to register on the radiograph. Radiographs were taken from a number of additional angles but reveal very little in addition to what is registered on the dorsal and ventral views herewith presented in Fig. 5.

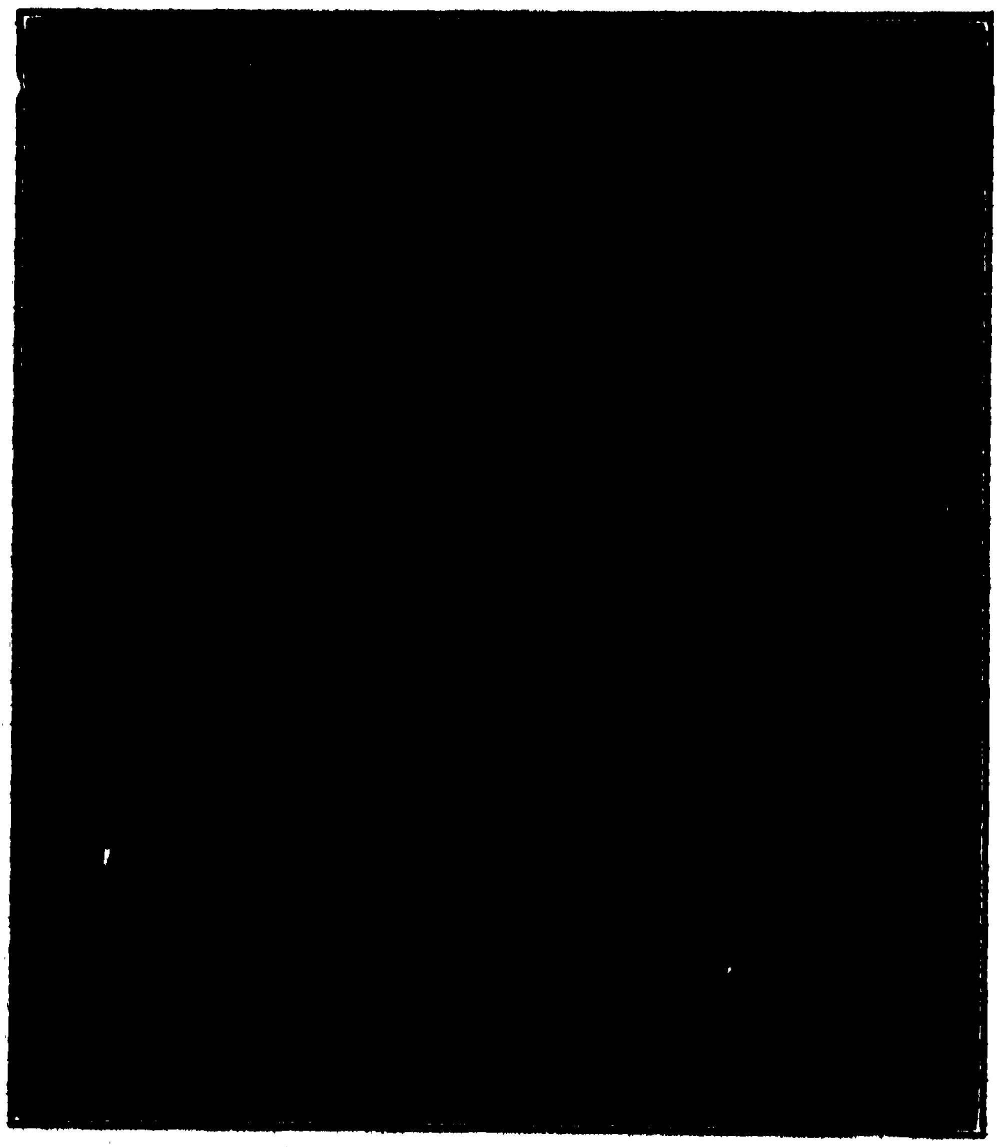

FIG. 5. RADIOGRAPHS OF TWIN TURTLE.

We have not been able to make an exhaustive study of the literature on this subject, but through the kindness of Dr. E. W. Gudger, of the American Museum of Natural History, have been able to compare the specimen with the description and figures of two somewhat similar specimens.

Barbour[2,3] has described a young tortoise of the same species which resembles the subject of this paper in several particulars. His specimen also had two heads and necks, as shown in his figures, which are herewith reproduced. His specimen was a trifle broader than long. The specimen we describe is one twelfth longer than broad. His specimen had two extra gullar plates, as against one in this specimen. His specimen had a single carapace, as compared to the two almost complete carapaces of this specimen. His specimen had one nuchal and two pygal plates in contrast to the two nuchal and one pygal of this specimen. The fifth neural plate is abnormal on both. His specimen also had a mid-ventral scar but not as prominent as on this one.

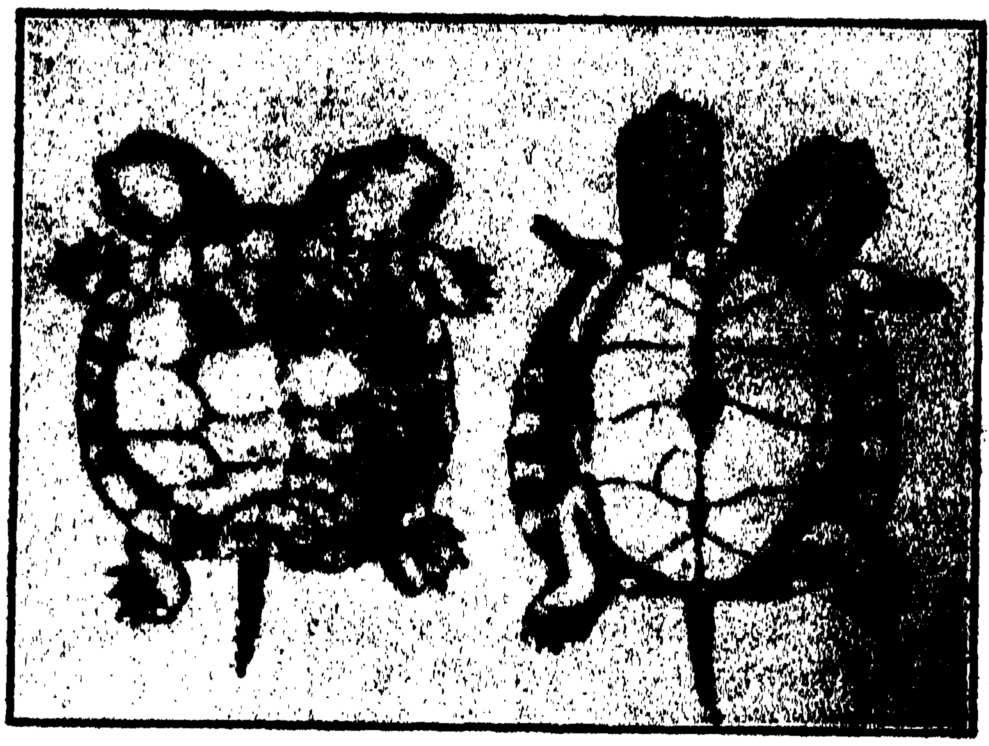

FIG. 6. DORSAL AND VENTRAL VIEW OF TWO-HEADED TORTOISE, CHRYSEMYS PICTA, AFTER BARBOUR.

The external evidence of twinning is carried much farther on this specimen than on Barbour's.

Barbour's account includes a very interesting series of observations on the behavior of his specimen from soon after hatching in June until its death, caused by a cat scratch, in September of the same year.

Bernard[4] reviewed Barbour's first article in *Cosmos* shortly after it appeared.

Hennig[5] gives an interesting account of the behavior of another somewhat similar specimen found in 1869.

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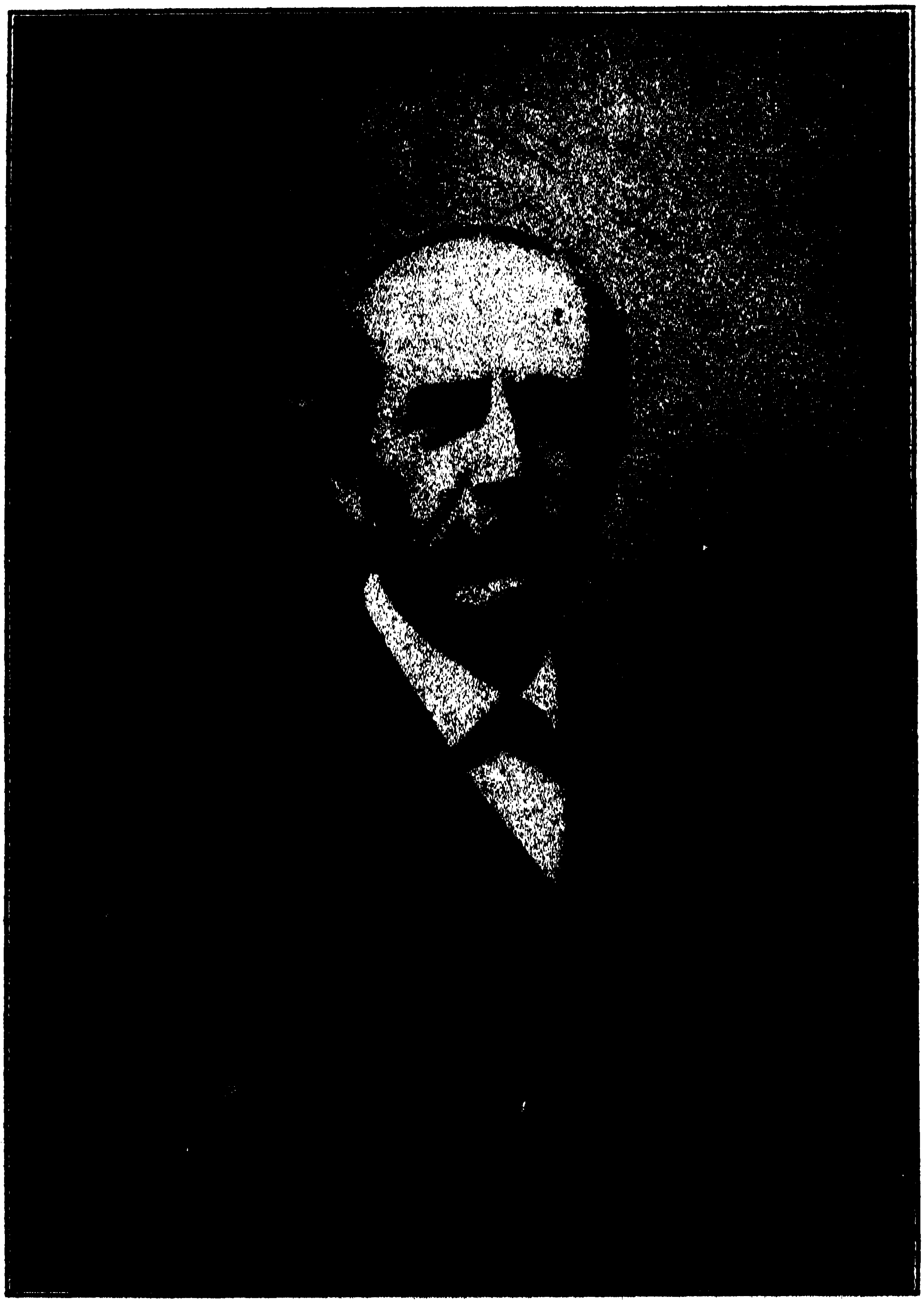
[2] Barbour, E. H., "On a Young Tortoise, Chrysemys picta, with Two Heads," *American Journal of Science*, third series, Vol. XXXVI, No. 214, October, 1888.

[3] Barbour, E. H., "A Two-headed Tortoise," *Science*, n. s., Vol. IV, No. 84, p. 159.

[4] Bernard, S., "Une Tortue à Deux-Tetes," *Cosmos*, 200, pp. 454–455, October, 1888.

[5] Hennig, Dr. C., "Einie Zweikopfige Eidechse," *Cosmos*, revue encyclop, hebdom. des progres des sciences, (v. Mennier), Paris, 21 August und 31 Juli, 1869.



MARCELLIN PIERRE EUGENE BERTHELOT

THE PROGRESS OF SCIENCE

THE BERTHELOT CENTENARY

Marcellin Berthelot was born in Paris on October 25, 1827, and the exact centenary of his birth was celebrated in Paris by the laying of the foundation-stone of the new International House of Chemistry, to be erected as a memorial to him. Subscriptions have been received from forty nations amounting to over fifteen million francs, one half of which has been given by France. Contributions from the United States amount to about five hundred thousand francs, but the American Chemical Society has taken exception to any official support by the society or the federal government, having at its recent Detroit meeting adopted a statement to the effect that "The American Chemical Society has naught but good wishes for the 'Chemists' Club' of New York, the long considered 'House of Chemistry' of Great Britain, the 'Hofmann House' of Berlin, or for a national 'Maison de la Chimie' to be located in Paris and would be glad to see any of its members, who are so inclined, contribute to their support. It can not, however, admit the propriety of any national group assuming the right to centralization of control of international chemistry within its own territory and sphere of influence, even if the major costs of construction and upkeep of such an institution were not assessed upon the rest of the world. The American Chemical Society believes that if an International Office of Chemistry, having as its object the centralization of influence of chemical science, both pure and applied, is ever deemed desirable or necessary, it should be inspired through cooperative action of the world's scientific chemical organizations and not by governments through political channels."

The principal address at the ceremonies of the laying of the corner-stone (the site of the building has in fact not yet been chosen) was by M. Donet-Agache, president of the French Society of Chemical Industry, who is reported to have said: "The International Chemical House will be of great value to all and not, as some believe, a luxury for a certain section of intellectual workers. Its purpose is similar to that of the great Pasteur Institute and other notable schools and laboratories. It will be a true meeting ground for scientific life, where professors, scholars, business men and savants of the whole world can come together and exchange ideas. The house will place at their disposition all the resources of a great technical library, and also all available publications, as issued. It will be headquarters for those savants and foreign business men who desire to cement and continue private relations, for which the recent World Chemical Congress demonstrated the necessity as well as demonstrated their worth. It will add to our dear Paris, city of art and beauty, a world intellectual center where disciples of Berthelot can renew the sacred fire of their calling."

M. Donet-Agache concluded by explaining that in constructing the International House in Paris, France sought no chemical hegemony, even of a scientific nature, but was merely carrying out in the domain of science the dream of Berthelot.

According to the report printed in *Nature* the proceedings began with a reception at the Sorbonne on the evening of Sunday, October 23, by M. Charléty, the rector of the University of Paris. On Monday morning, in the presence of representatives of the French Government, a museum of apparatus and manuscripts relating to Berthelot was opened at the Faculty of Pharmacy by Professor Radet; the visitors were next received at the Collège de France by M. Croizet; after speeches by the president of the German Chemical Society, Professor Schlenk, and Professor Bogert, of Columbia University, Berthelot's former laboratories and apparatus were inspected. Later, a memorial tablet was unveiled on the wall of Berthelot's early residence, 113 Rue Saint Martin, and speeches were made by M. Boujou, Préfet de la Seine.

The chief meeting was held in the large amphitheater of the Sorbonne on the evening of October 24; discourses were pronounced by Professor Ch. Moureu on the work of Berthelot, and by Professor Lacroix, secretary of the Academy of Sciences; M. Georges Lecomte, director of the Académie française; M. Gley, president of the Academy of Medicine; M. Wéry, president of the Academy of Agriculture; M. Hodza, Minister of Education for Czecho-Slovakia, and by M. Paul Painlevé. Addresses were presented on behalf of numerous academic bodies; it is indicative of the wide-spread interest in the celebration that the first addresses handed in were those from Abyssinia and Afghanistan.

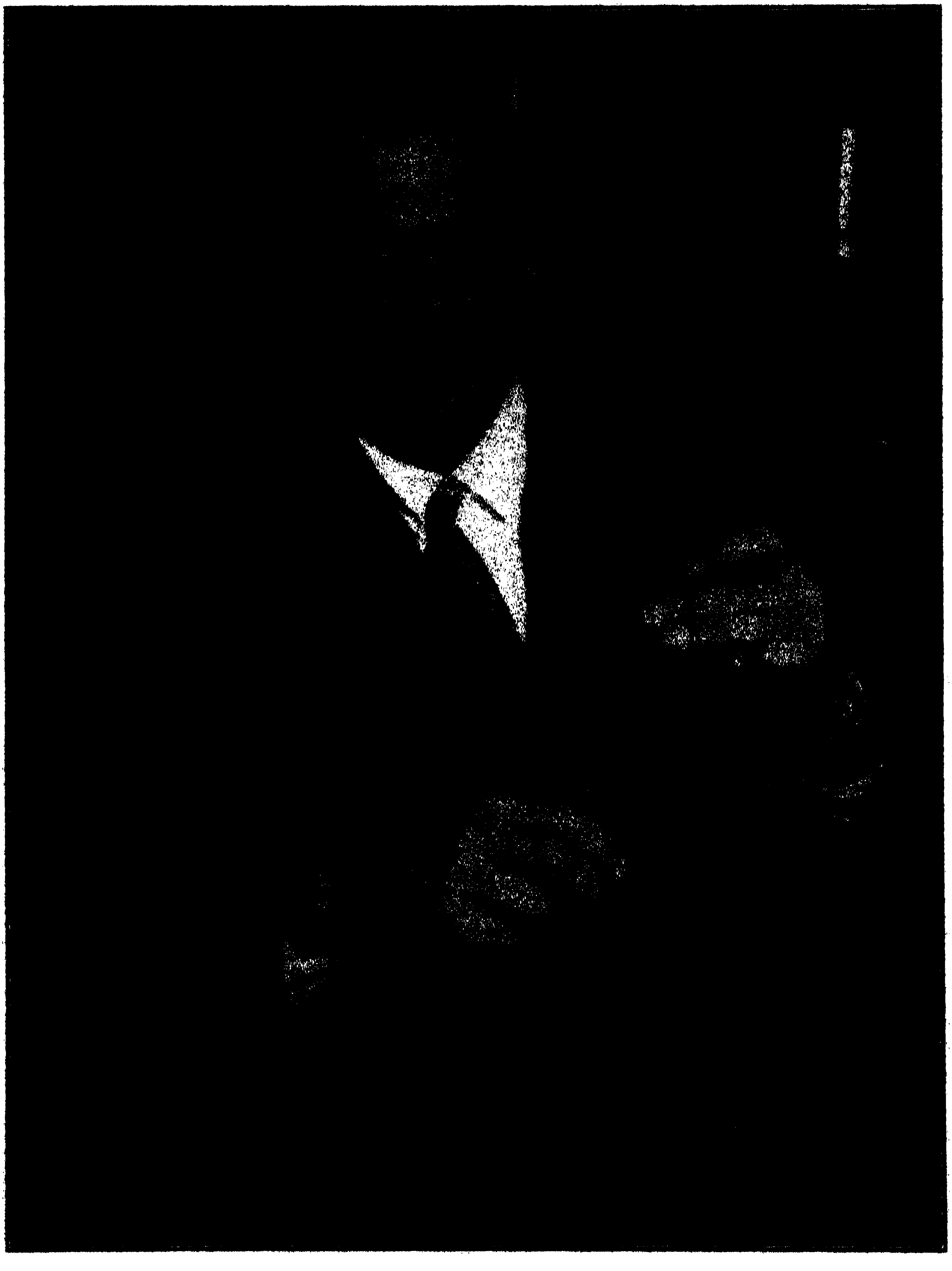
A commemoration ceremony took place at the Panthéon on Tuesday morning, October 25, when speeches were made by M. Raymond Poincaré and by M. Galliardo, minister of foreign affairs of the Argentine Republic. This was followed by a lunch in the Galérie des Batailles at Versailles, which was attended by some 1,200 guests, and discourses were delivered by M. Herriot, minister of education; Professor Amé Pictet, of the University of Geneva, and M. Lunatcharsky, minister of education to the Union of Socialist Soviet Republics.

On Wednesday morning, October 26, the foundation-stone of the new House of Chemistry was laid in the Place d'Iéna by M. Herriot; M. Donat-Agache, president of the French Society of Chemical Industry; M. Zumeta, the Venezuelan Minister, and Professor Ernst Cohen, of Utrecht, spoke, and the party adjourned for lunch to the château belonging to the French Academy at Chantilly, where discourses were pronounced by M. Lecomte, director of the French Academy, and Professor H. E. Armstrong. In the evening the delegates were received by President Gaston Doumergue at the Palais de l'Elysée. It is proposed to issue a commemorative volume giving a full account of the proceedings of the Berthelot centenary celebrations.

RADIUM AT THE MEMORIAL HOSPITAL

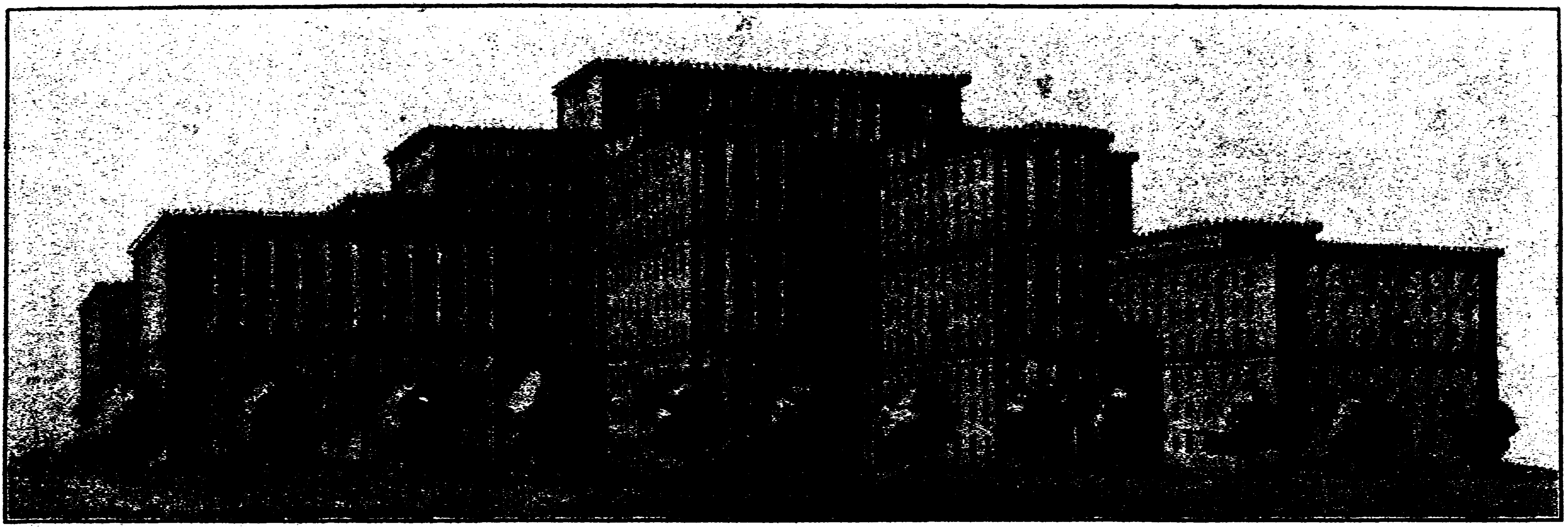
THROUGH the generosity of the late Dr. James Douglas, the Memorial Hospital of New York City, during the last ten years, has had in its possession four grams of radium for the treatment of cancer and allied diseases. Recently a gift of $250,000 from Mr. Edward S. Harkness has made it possible for the hospital to increase its radium supply to eight grams, which is the largest amount controlled by any institution. While the first four grams are kept in solution, to provide a constant supply of radon (radium emanation), which is then used for therapeutic purposes, the last four grams are kept in a special container which is applied directly to the patients.

Before describing this apparatus, it may be well to outline briefly how radium is used for the treatment of cancer. In the first place, it should be noted that radium is not used as a drug.



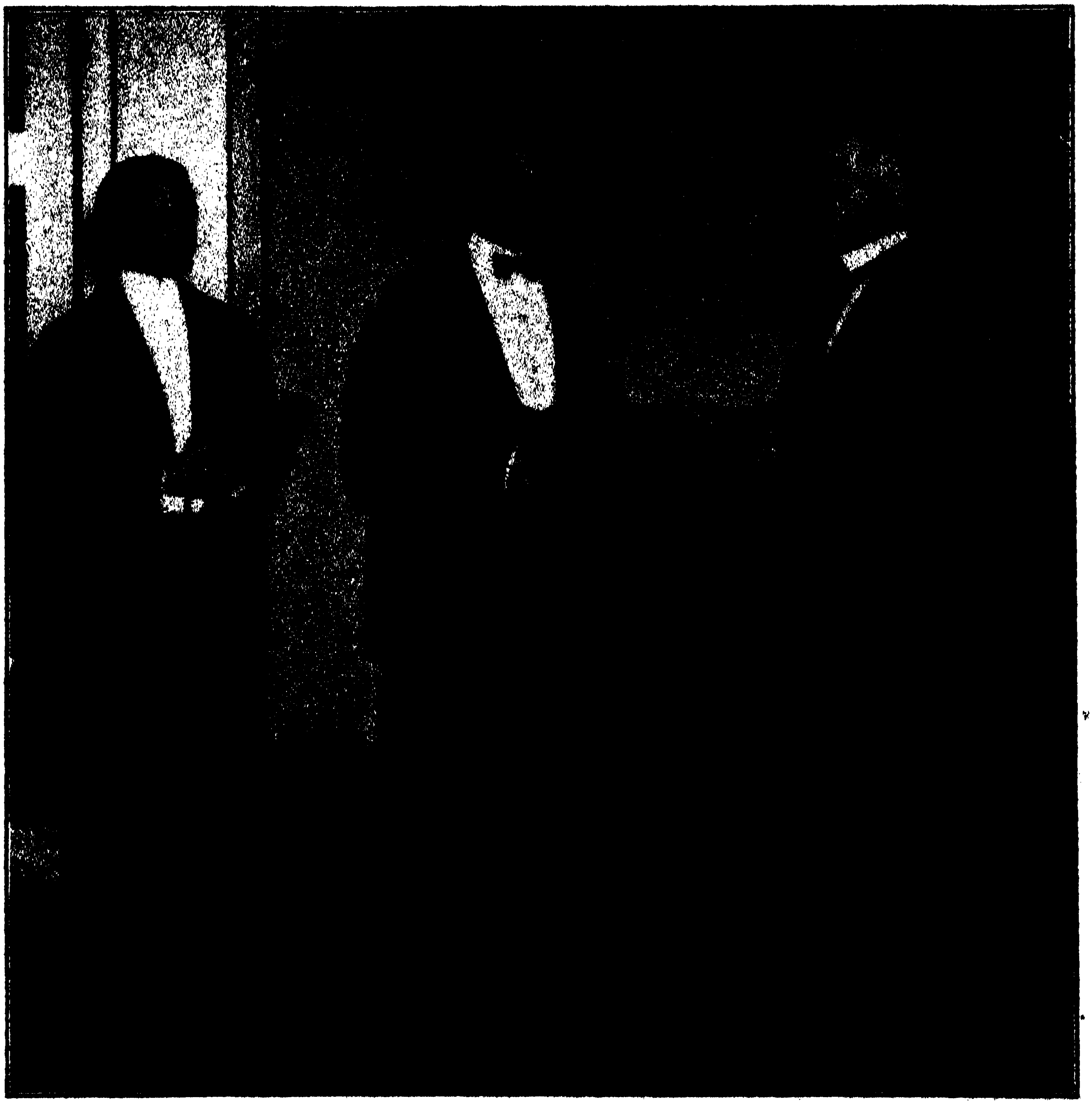
ARTHUR H. COMPTON

TO WHOM THE SWEDISH ROYAL ACADEMY OF SCIENCE HAS AWARDED THE NOBEL PRIZE IN PHYSICS IN CONJUNCTION WITH PROFESSOR CHARLES THOMPSON REES WILSON, OF THE UNIVERSITY OF CAMBRIDGE. PROFESSOR COMPTON IS HERE SHOWN WITH HIS X-RAY SPECTROMETER. THE NOBEL PRIZE IN PHYSICS HAS PREVIOUSLY BEEN AWARDED IN THE UNITED STATES TO PROFESSOR A. A. MICHELSON, OF THE UNIVERSITY OF CHICAGO, AND TO PROFESSOR ROBERT A. MILLIKAN, OF THE CALIFORNIA INSTITUTE OF TECHNOLOGY. PROFESSOR KARL T. COMPTON, OF PRINCETON UNIVERSITY, THE BROTHER OF PROFESSOR ARTHUR H. COMPTON, IS ALSO A DISTINGUISHED PHYSICIST.



THE NEW YORK HOSPITAL AND CORNELL UNIVERSITY MEDICAL CENTER

The architects' drawing shows the southern front of the proposed building which will house the New York Hospital and the Cornell University Medical School and is to be erected at a cost of $11,000,000. An adequate endowment fund for the combined institutions is planned, and a sum of $25,000,000 is already available, largely from legacies provided in the will of the late Payne Whitney and an appropriation of $7,500,000 from the General Education Board. The New York Hospital-Cornell University Medical College Association—as the combined institutions are officially designated—will occupy two blocks of land immediately north of the Rockefeller Institute for Medical Research. The architects, Messrs. Coolidge, Shepley, Bulfinch and Abbott, have acted in the same capacity for the medical schools of Harvard University, Vanderbilt University and other institutions. Dr. George Canby Robinson, who is the present dean of the Medical School of Vanderbilt University, will be the director of the new medical unit which will be ready for occupancy in 1930.



—*Wide World Photos*

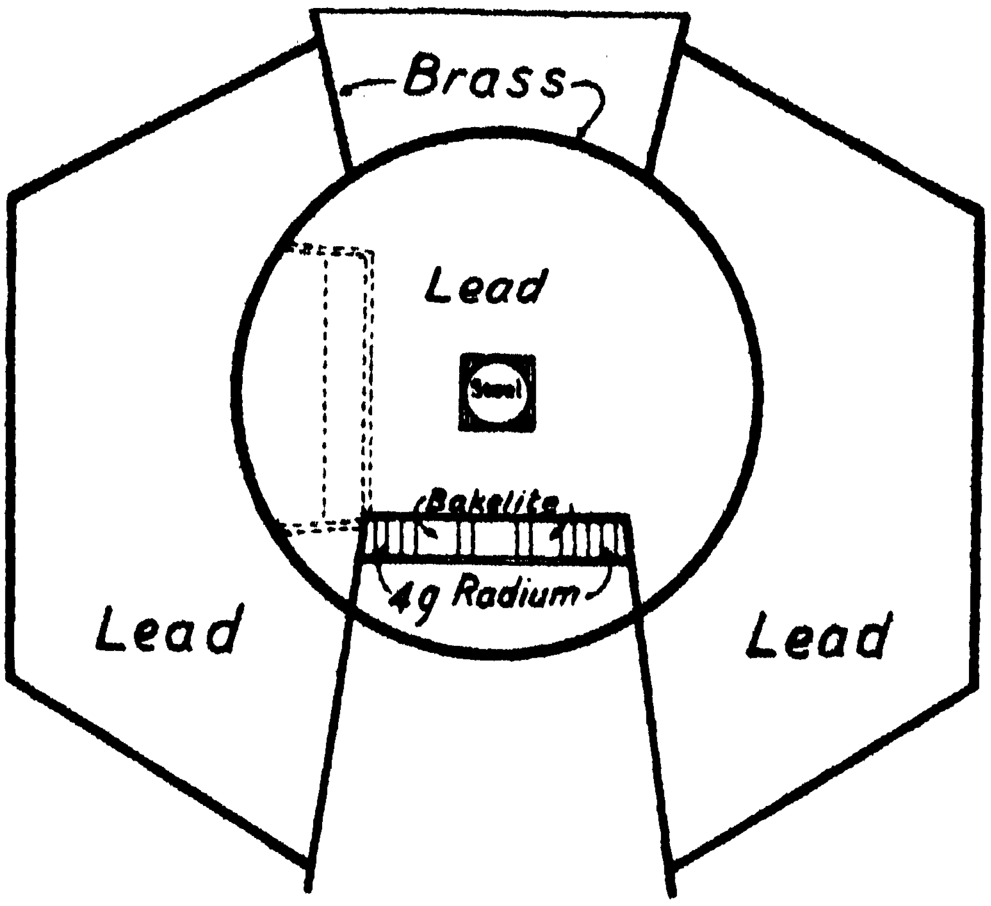
CONFERRING OF THE JOHN SCOTT MEDALS

The photograph shows Dr. Herbert A. Hare, distinguished for his work in experimental therapeutics, presenting John Scott Medals to Dr. Alfred F. Hess, of Columbia University, and Dr. Afrano do Amaral, of the Antivenin Institute of America at Glenolden, Pennsylvania. A medal was also conferred on Dr. Peyton Rous, of the Rockefeller Institute for Medical Research, whose work has been concerned largely with the transplantation of cancerous cells in chickens. Dr. Hess has in recent years been engaged in the study of ultra-violet light, especially in its relation to rickets. Dr. do Amaral, a native of Brazil, has played an active part in the development of serums which can be used to prevent deaths from snake bites. The fund from which the award is made was established over a century ago when John Scott, an Edinburgh chemist, bequeathed $4,000 to the City of Philadelphia. This was to be "laid out in premiums to be distributed among ingenious men and women who make useful inventions." It is now awarded on the advice of a committee consisting of representatives of the University of Pennsylvania, the American Philosophical Society and the National Academy of Sciences.

That is, it is not administered to the patient in the form of pills, powders, solutions, salves, etc. In fact, it never comes in actual contact with the patient. Its action is due to the powerful rays which it emits constantly and spontaneously. The gamma rays, which are the ones chiefly used for the treatment of cancer, are capable of passing through opaque substances with little absorption. Therefore, radium can influence living tissues not only without actual contact, but even through a sheet of metal several millimeters thick.

Radium rays are capable of affecting all living tissues. The effect may vary from an imperceptible one to complete destruction, depending on the amount of radiation which has been absorbed by the tissue. Some tissues are more easily affected than others. Thus certain types of cancer are more susceptible to radium rays than the normal tissues surrounding the tumors, while other types are less susceptible. Remembering that the object of radium therapy is to get rid of a tumor without serious injury to the normal tissues or the patient as a whole, it will be seen that the particular method of applying the radium depends largely on the type of cancer one is dealing with and its location. Sometimes it is necessary to place the radioactive source within the tumor mass itself; sometimes surface applications are sufficient; in other cases it may be desirable to place the radium at a distance of several centimeters from the surface. The four grams of radium recently acquired by the Memorial Hospital are used exclusively for such external applications.

The design of a suitable container for this purpose must fulfil two essential requirements which are more or less antagonistic. That is, the container must afford sufficient protection to the operator who applies it, and at the same time must be sufficiently flexible to make possible its adjustment to any part of the patient's body. On account of the great penetrating power of gamma rays, a large mass of lead is required around the radium, and this makes it impossible to rest the container on the patient's body. The appliance used at the Memorial Hospital is suspended from a horizontal beam, which is moved up and down as a whole by an electric motor.



RADIUM CONTAINER

CROSS-SECTION OF CONTAINER USED FOR EXTERNAL APPLICATIONS. GAMMA RAYS FROM THE FOUR GRAMS OF RADIUM PASS THROUGH 0.5 MM. OF PLATINUM AND 2 MM. OF BRASS BEFORE REACHING THE PATIENT. THE AVERAGE THICKNESS OF THE LEAD PROTECTION IS 10 CM.

A cross-section of the container is shown in Figure 1, and a photograph in Figure 2. Forty platinum capsules, each containing 100 milligrams of radium, are distributed over a (bakelite) circle 7.5 cm. in diameter. This disc is inserted into a recess milled out of the side of a lead cylinder 15 cm. in diameter and 28 cm. long. The cylinder is fitted into a large lead casting of the shape shown, and is supported coaxially by a steel shaft running on ball bearings. By this arrangement it is possible to turn the cylinder so that the radium is pointed towards one or the other of the two openings provided in the lead casting; or it can be placed in the position shown by

PHOTOGRAPH OF RADIUM CONTAINER

Showing method of support and flexibility of adjustment.

the dotted lines in Figure 1, in which case the radium is completely surrounded by lead. The lead cylinder weighs about 200 pounds, but it can be turned easily by a handle attached to the shaft. The lead casting which houses the cylinder is covered with a thick brass shell, and is thereby attached to a bronze ring. Two steel studs are fastened to this ring at right angles to the cylinder, and these run on ball bearings in a steel yoke. The latter is suspended from a carriage rolling on the horizontal beam, and is capable of rotation on a vertical axis by means of a stout stud running on a ball bearing. In this way it is possible to adjust the beam of rays emerging from either opening in any desired orientation. As already mentioned, the horizontal steel beam can be moved up and down. The carriage can be rolled along this beam, and the table, on which the patient lies during the treatment, can be moved longitudinally on tracks placed at right angles to the steel beam. Thus with this arrangement it is a simple matter to place the heavy lead container (weighing about 500 pounds) over any desired part of the body in the proper orientation.

An ordinary set-up can be made in three minutes. Treatments last from one to several hours. A technician stays in an adjoining room and observes the patient every fifteen minutes through a small window in a lead-lined partition. This additional protection for the operator, and hospital personnel in general, is necessary on account of the radiation which is scattered by the patient's body and other matter in the path of the beam of rays.

GIOACCHINO FAILLA, *Physicist*

THE NATIONAL FORESTS AREA

THE total area of the national forests was increased by 41,214 acres in the last fiscal year, according to the latest check just completed by the Forest Service.

The aggregate net area of national forests on June 30, the close of the last fiscal year, was 158,800,424 acres. Included within the boundaries of the national forests was a gross area of 183,938,106 acres, of which 25,137,682 acres was alienated land.

With the separation of the Ocala National Forest, formerly a division of the Florida National Forest, as a distinct unit by recent proclamation of the president, there are now 160 national forests in the country, located in 32 states and in Alaska and Porto Rico.

The total net gain in area of national forests last year was not as large as the gain in several preceding years. This was due in part to the fact that a considerable acreage was transferred by special acts of the congress to national parks. The forests also were drawn upon to some extent in the consummation of state exchanges and consolidations. Net reductions in area were shown in the following states and territories: Alaska, 2,780 acres; California, 193,164 acres; Colorado, 19,399 acres; Nevada, 412 acres; New York, 6,154 acres (this reduction being due to the release of Camp Upton Military Reservation from national-forest status), and South Dakota, 1,776 acres.

The largest increase was 65,274 acres, this in Pennsylvania. Washington was second with a net increase of 63,084, followed by Wyoming with an increase of 42,494 acres, Georgia with 34,967, New Mexico with 27,084, Oregon with 21,852, Arizona with 20,230 and others with smaller amounts.

Up to the close of the last fiscal year lands acquired for national forests in the Eastern and Southern States under the Weeks law amounted to 2,564,619 acres, and an additional 328,122 acres has been approved for purchase.

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